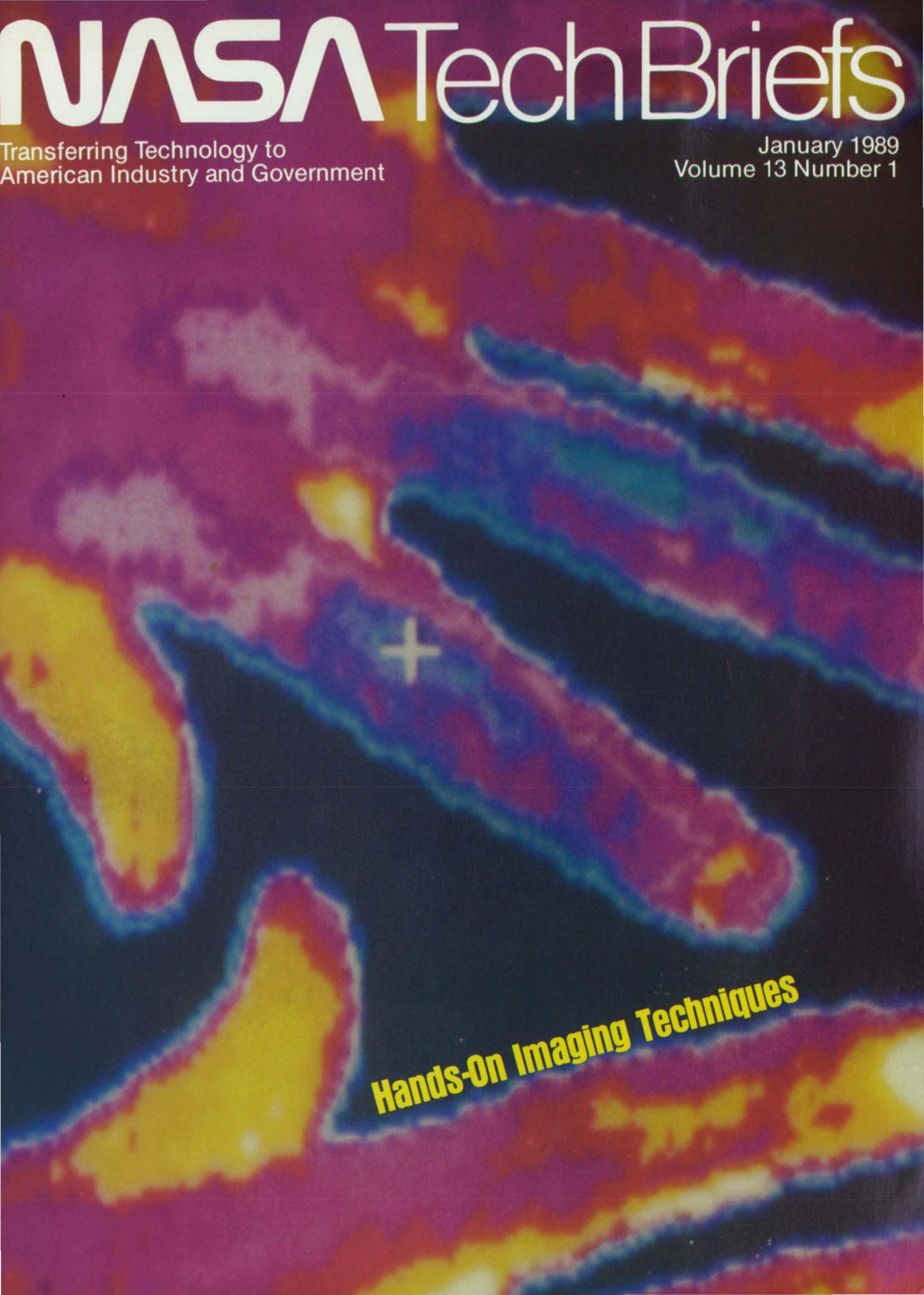
NASA Tech Briefs

Transferring Technology to
American Industry and Government

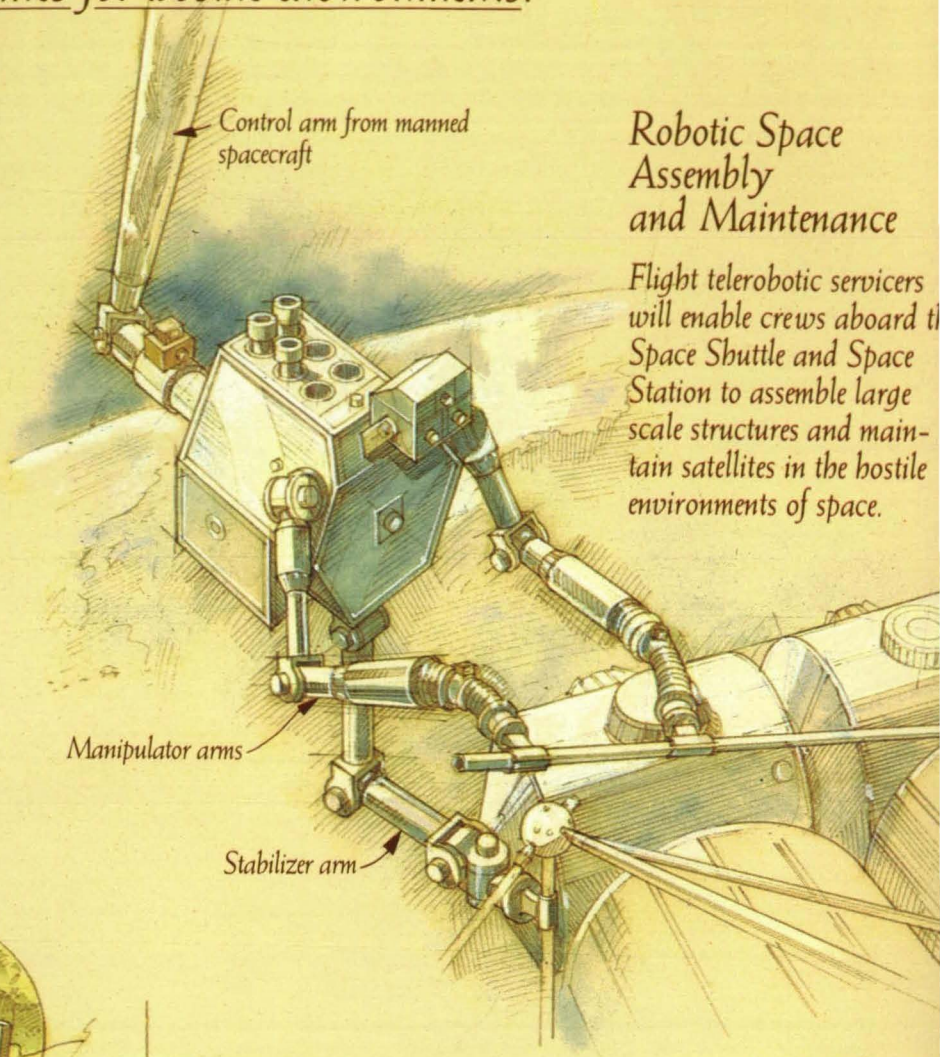
January 1989
Volume 13 Number 1



Hands-On Imaging Techniques

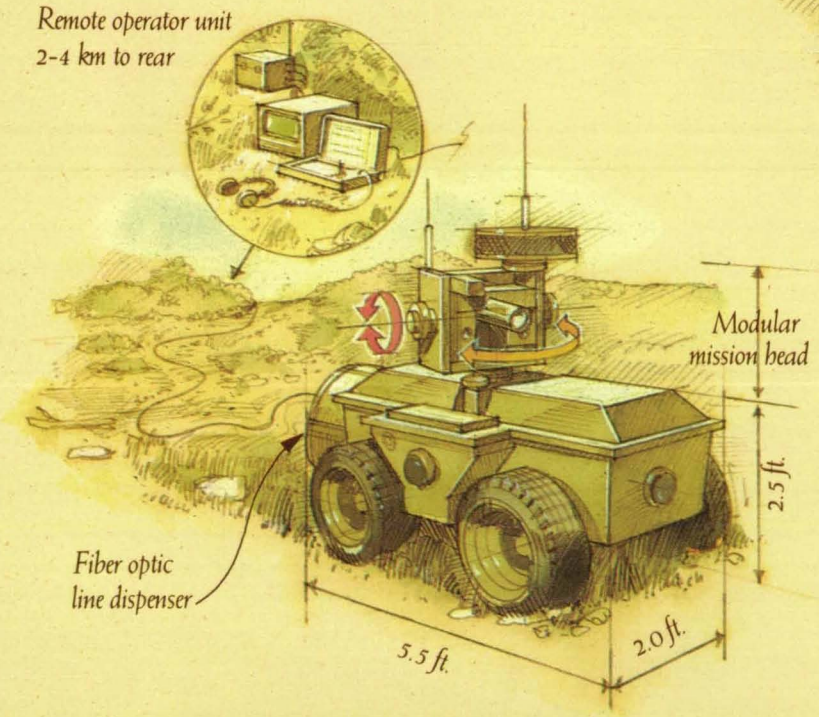
High-technology machines for hostile environments.

On the ground, in the air, in space, beneath the sea – wherever hostile or hazardous conditions exist, new generations of independently functioning, "intelligent" machines are being created to assist man's performance in these adverse situations. Many of these machines, including autonomous and remotely controlled land vehicles, aircraft, spacecraft and submersibles, will rely heavily on advanced technologies in artificial intelligence and robotics being developed at Martin Marietta.



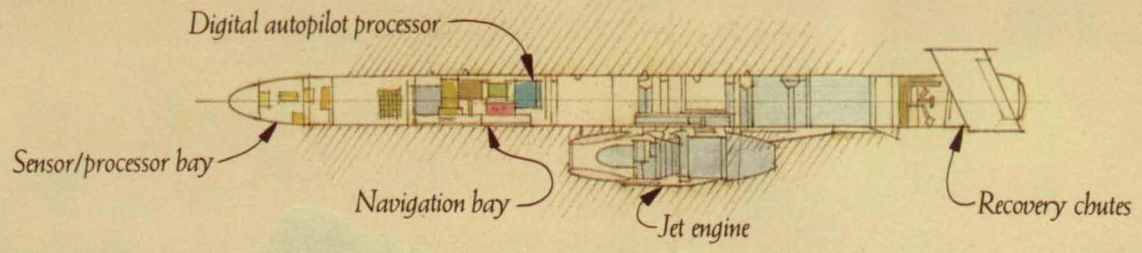
Robotic Space Assembly and Maintenance

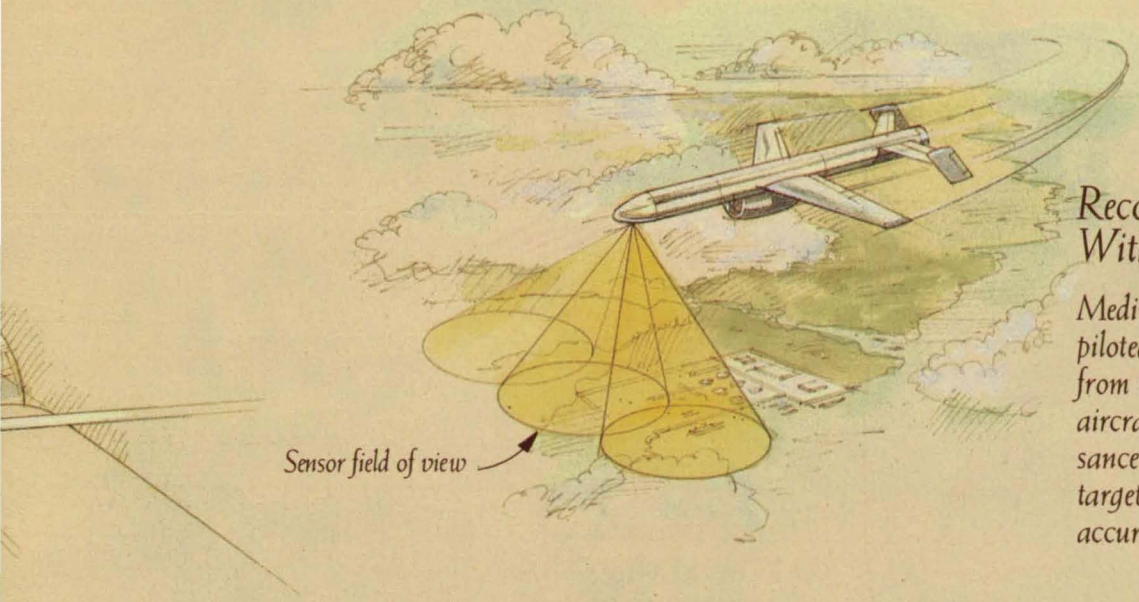
Flight telerobotic servicers will enable crews aboard th Space Shuttle and Space Station to assemble large scale structures and maintain satellites in the hostile environments of space.



Robots Prepared for Action

Advanced remotely controlled robots, many utilizing artificial intelligence, have wide-ranging military applications. Vehicles for reconnaissance, target designation, weapons platforms, resupply and medical evacuation will improve troop survivability and provide force multipliers for battlefields of the future.



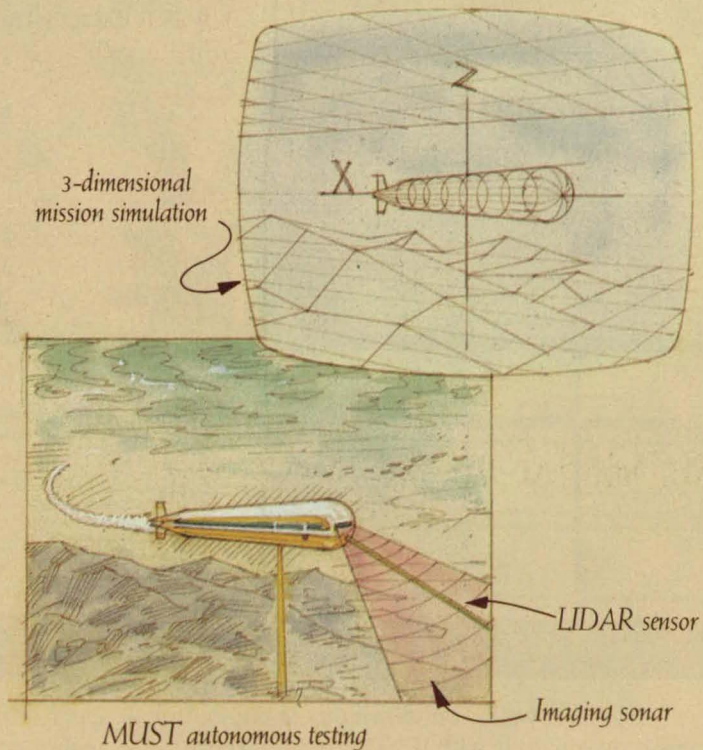


Reconnaissance Without Risk

Medium-range, remotely piloted aircraft launched from the ground or other aircraft will fly reconnaissance missions and identify targets with pinpoint accuracy.

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MUST autonomous testing

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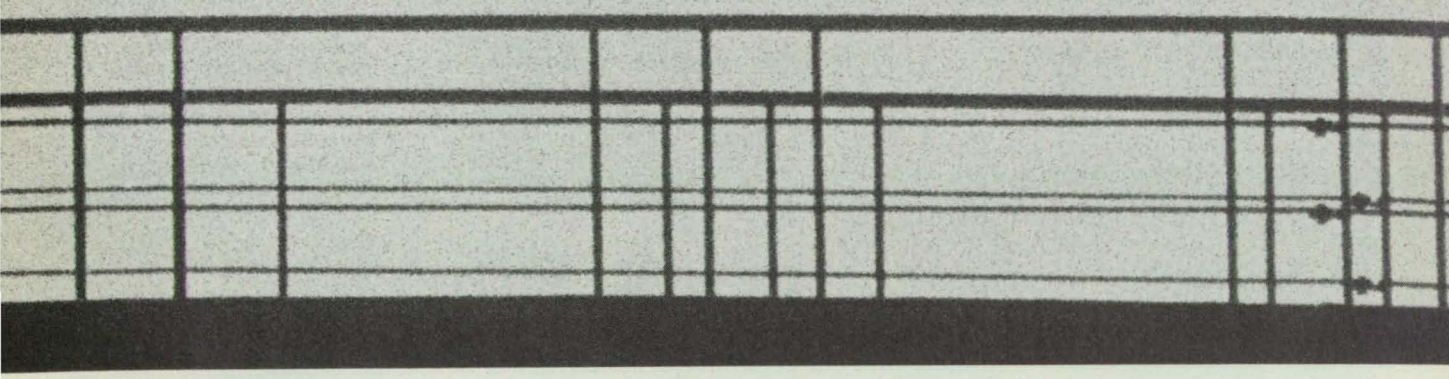
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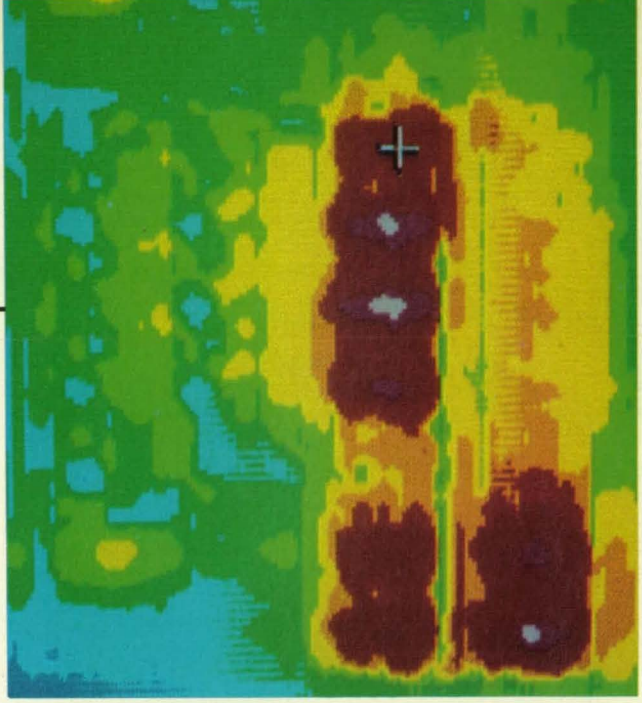
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Engineers can detect and locate defects in printed circuit boards (PCBs) using a video system that records thermal radiation in the same way a camera records light reflection. The above thermograph depicts the heat distribution in a properly functioning PCB, which can serve as a reference in checking other boards for failures. See page 92.
(Photo courtesy Hughes Aircraft Company, Carlsbad, CA)

DEPARTMENTS



This man used NASA-derived technology and a $27 investment to launch what is now a multimillion dollar a year business. Turn to page 12.
(Photo courtesy the Water Filter Company of America, National City, CA)

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On The Cover: Infrared imaging provides a handy tool for the detection of circulatory problems and other conditions evidenced by variations in skin temperature. Turn to Mission Accomplished, page 92.
(Photo courtesy Hughes Aircraft Co.)

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The Viscous Criterion



The Viscous Criterion

Two scientists at the General Motors Research Laboratories have developed a way to predict the probability and severity of impact injuries in the body's soft tissues, including the heart, liver, and the central nervous system. It is an essential step in designing safety systems to reduce such injuries.

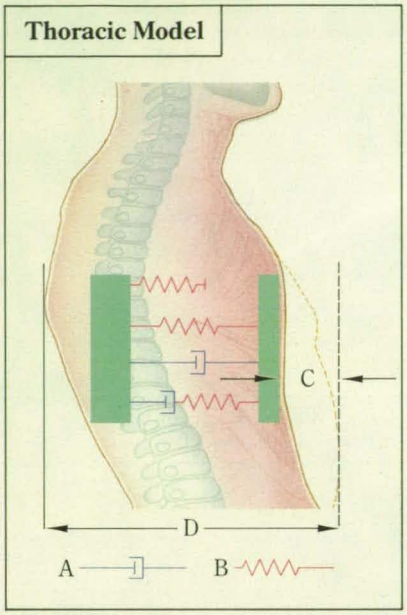


FIGURE 2: Lateral view of a viscoelastic model of the human chest. Dashpot elements (a) and spring elements (b) represent thoracic compliance. Compression (C) is expressed as a percentage of original chest depth (D).

Designing an automobile to reduce the risk of injury to its occupants in a collision demands an ability to correlate the forces generated by the crash with the biological effects experienced by the people involved.

Military rocket sled experiments in the late 1950s measured man's ability to withstand sudden changes in speed. The resulting Acceleration Criterion was used in setting 60g (60 times the force of gravity) as the maximum spinal acceleration allowable under federal motor vehicle standards in a 30 mph crash test.

This Acceleration Criterion treats the body as a rigid structure. Over the years, however, subsequent research on injury mechanisms indicates that injury criteria based on whole-body acceleration are incomplete predictors of injury risk.

The body is a deformable structure, and injury can be sustained when the chest is compressed in an accident. At low speeds of deformation (less than 3 meters per second), the tolerance to rib cage damage and the risk of injury correlate closely to the maximum compression of the chest—expressed as a percentage of the original chest depth from sternum to spine. This Compression Criterion, developed in the early '80s by GM researchers in conjunction with the University of California at San Diego, is useful in evaluating injury risk for safety-belted occupants, where tight coupling to vehicle deceleration reduces the amount of chest compression in a collision.

Doctors Ian Lau and David Viano—both members of the Biomedical Science Department of the General Motors Research Laboratories—began in 1981 to evaluate the importance of velocity in assessing the risk of impact injury. They were concerned that the maximum compression tolerance might underestimate chest injury risk at high speeds of chest deformation (greater than 3 m/s)—typical of unrestrained occupants in a frontal crash, or in high-speed side impacts.

The two scientists designed a series of experiments that held maximum compression constant at 16%—well below the tolerance level of 35%—and varied the rate of abdominal compression from 5 m/s to 20 m/s. The experiments verified that severity of soft tissue injury increased as the velocity of compression increased.

These results, plus further analysis of previous experiments, led Viano and Lau to develop a function called the *Viscous Response* to describe the behavior of soft tissue during an impact event. Viscous Response was defined as the instantaneous product of the velocity of deformation and compression, varying over time: VC(t) (Figure 1A).

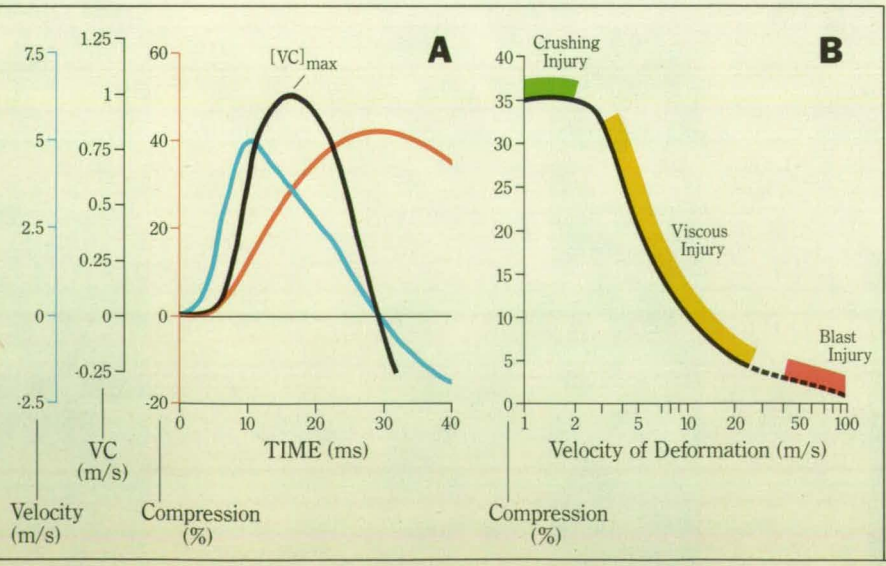


FIGURE 1: A) Plot of viscous response, VC(t), during impact (black). C(t)=normalized compression (red). V(t)=rate of chest deflection (blue). $[VC]_{max}$ defines the Viscous Criterion. B) Range of validity for Viscous Criterion (yellow).

The mathematical form of the Viscous Response is derived from analysis of a mechanical analog of the viscoelastic response of the human thorax. (Figure 2). The dashpots (2a) represent the behavior of viscous soft tissue, while the springs (2b) correspond to the elastic skeletal response to impact.

In computing impact energy absorbed by the analog, the dominant term is the product of velocity of deformation and compression, with compression defined as chest deflection normalized by the original chest depth, (Fig. 2, D). Therefore, the Viscous Response is related to absorbed energy.

Drs. Viano and Lau suspected that the injury mechanism for soft tissue was also related to absorbed energy, and designed further experiments to verify the predictive abilities of the peak Viscous Response (VC_{max}). In these tests, velocities of deformation ranged from 5 m/s to 22 m/s and maximum chest compressions ranged from 4% to 55%. Analysis of the test data showed that the maximum Viscous Response was an accurate predictor of injury risk for the entire data set. In addition, VC_{max} was the only biomechanical response that adequately defined injury risk for the full range of test conditions, including the extremes of only 4% compression at 22 m/s, as well as 55% compression at only 5 m/s.

Investigation across this range of deformation velocities effectively links together existing knowledge of crushing injuries, high-speed impact injuries, and data available on blast injuries (Figure 1B).

Applying the Viscous Criterion to previously published blunt frontal impact data, Lau and Viano used statistical analysis to show that VC_{max} was highly correlated with the risk of severe injury. "For velocities of chest deformation above 3.0 m/s," says Dave Viano, "VC_{max} is the principal indicator of injury, whereas for very slow speeds of deflection, the Compression Criterion assesses crushing injury risk. We are, therefore, recommending a viscous tolerance for the chest of VC_{max} equal to 1.00 m/s, and a compression tolerance of C_{max} equal to 35% to minimize the risk of severe injury in an accident."

Ian Lau points out the importance of such risk assessments as targets for automotive designers. "Based on our new awareness of the mechanism of soft tissue injury, General Motors has already designed a self-aligning steering wheel that can be an excellent countermeasure for reducing abdominal injuries in a crash."

The new wheel works in concert with the energy-absorbing steering column, and is available as standard equipment on the 1989 Chevrolet Cavalier. Says Lau, "This is an excellent example of engineering and medical science working together. And because GM is the only auto maker with a biomedical research facility and a dedicated staff of research professionals, it can only happen here."

General Motors

GM

MARK OF EXCELLENCE



THE MEN BEHIND THE WORK:

David C. Viano and Ian V. Lau are both members of the Biomedical Science Department at the GM Research Laboratories.

Dr. Viano (right) is a Principal Research Scientist, leading the department's Safety Research Program. Dave received his BS in Electrical Engineering from the University of Santa Clara; he holds both an MS and a Ph.D. in Applied Mechanics from the California Institute of Technology. Dr. Viano joined GM in 1974 following postdoctoral work in Biomechanics at the Swiss Institute of Technology. His interests include technologies to improve occupant protection, the biomechanics of trauma and disability, transportation safety, and public health approaches to injury control.

Dr. Ian Lau came to the Research Laboratories in 1978, and is now a Senior Staff Research Engineer. Ian has a BS in Electrical Engineering from Lowell University. He holds a Ph.D. in Biomedical Engineering from the School of Medicine of the Johns Hopkins University. Ian was also a Postdoctoral Fellow of the American Heart Association at the Hopkins School of Hygiene and Public Health. His other research interests include traumatic cardiac arrhythmias, and occupant interaction with the steering and supplemental restraint systems.

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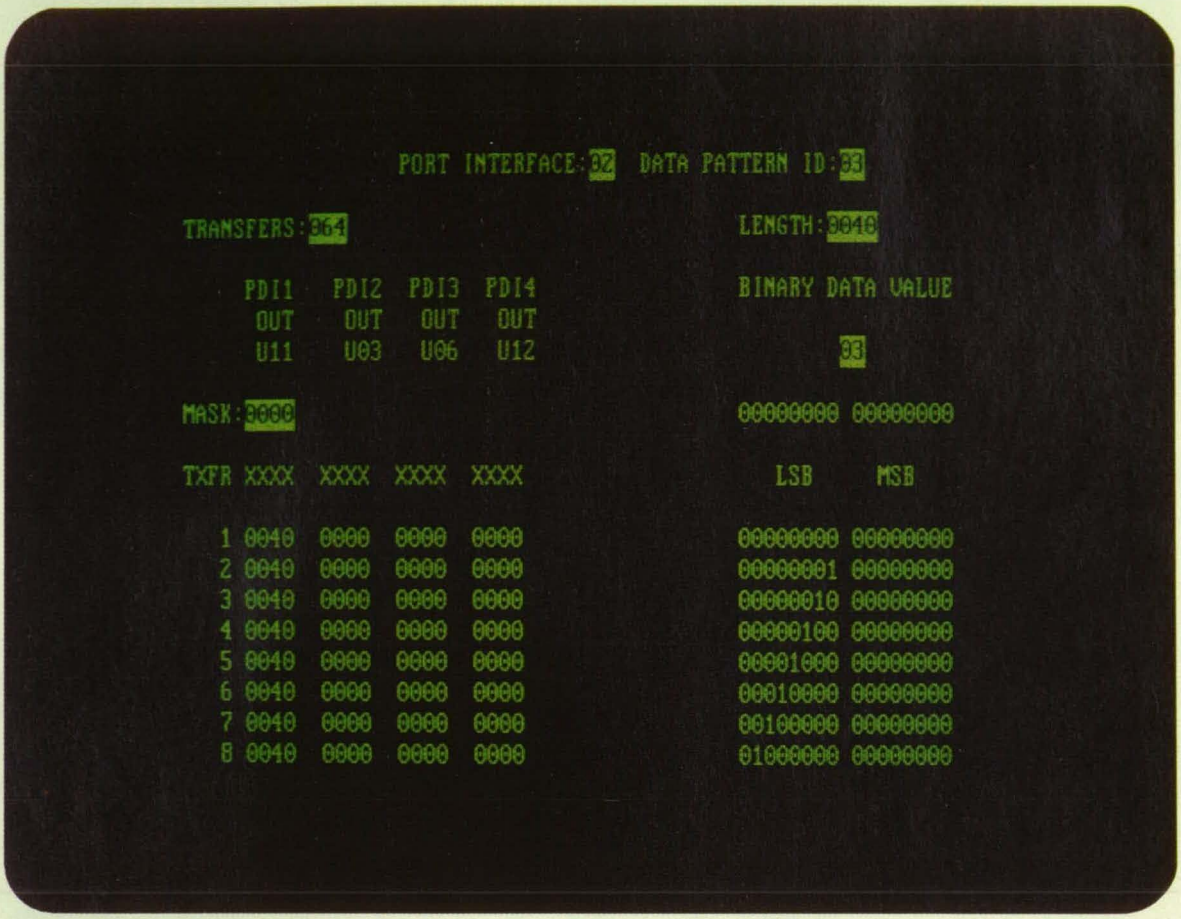


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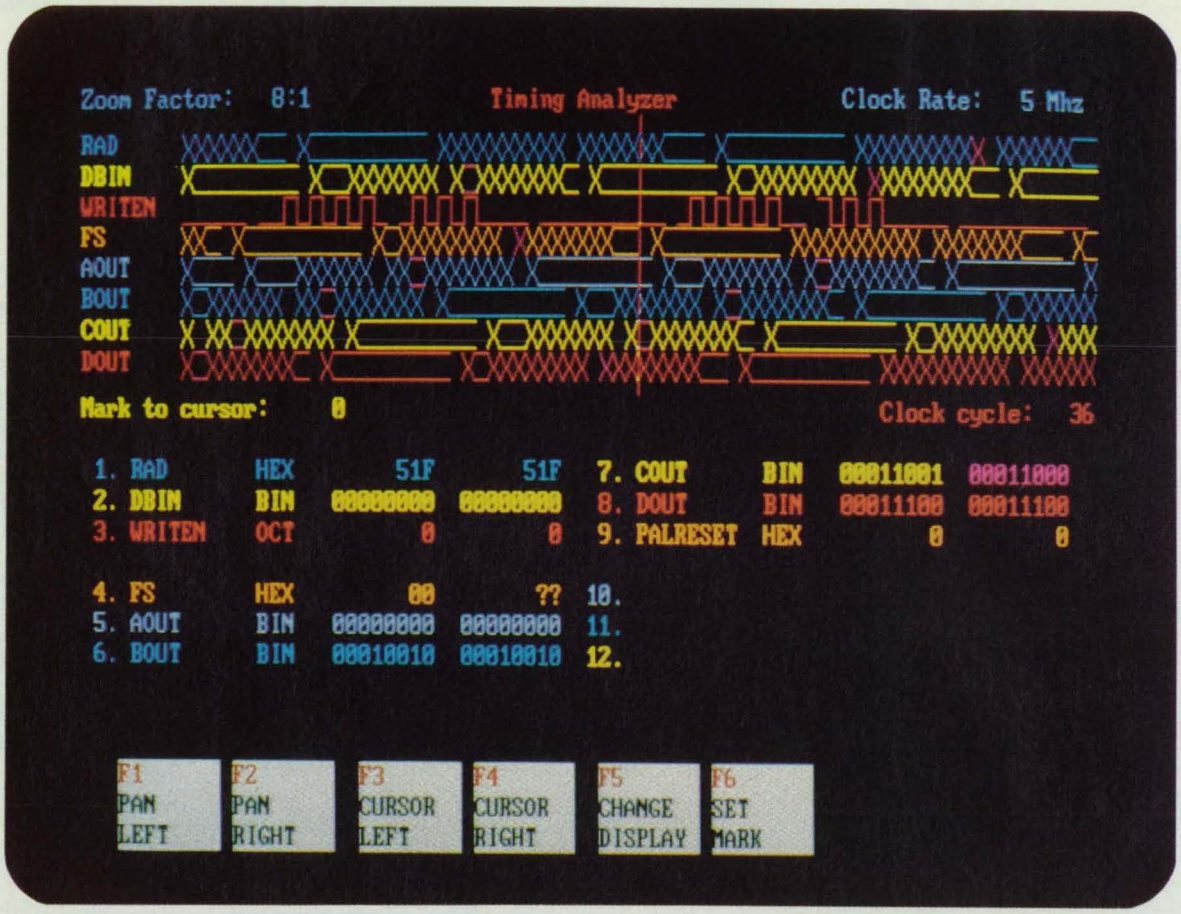
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INSIDE STIF: Technology Transfer In *Action*



When inventor Ray Ward moved to Arizona in 1976, he found he didn't like the taste of the tap water in his new locale. "It was kind of rusty," Ward said. "So I decided to build my own water filter, which at the time was a pretty novel idea."

While exploring various types of filtering systems, Ward learned of a compact, electrolytic filter NASA had developed to purify water aboard the Space Shuttle. He requested and received an information package on the shuttle filter from the Technology Utilization (TU) Office at NASA's Scientific and Technical Information Facility (STIF) in Baltimore, MD.

"The reports they sent were a great help," Ward recalled. "That information served as the basis for creation of my homemade device."

Ward used his last $27 to buy materials for the filter, which worked so well that soon friends and neighbors wanted one, and a new product was born—the Bon Del™ water filter. Today his idea has blossomed into a $50 million a year business called the Water Filter Company of America, which supplies clean water to more than a million people worldwide.

Ward's success story illustrates one of the many ways the NASA TU Office helps transfer space-based technology to other sectors of the U.S. economy. As the administrative arm of NASA's Technology Utilization Program, the office not only distributes scientific publications, but also fields a slew of technical questions and information requests daily, develops reference and bibliographic data, tracks new NASA spinoffs, maintains the subscription list for *NASA Tech Briefs*, and conducts public relations activities.

"Users of NASA's TU Program are sometimes confused as to where to turn for help," said Walter Heiland, Manager of the TU Office. "They should contact our office. We'll set them on the right path to get the information they need."

Heiland's 14-member staff receives hundreds of inquiries each day in the form of letters, phone calls, and questions written on *NASA Tech Briefs* feedback cards. "We never, ever turn away anyone with a question," said Heiland, "even if it has nothing to do with NASA programs per se. If we can't provide the information, we'll refer them to a person or place that will offer some answers. For instance, if someone inquires about new research on cancer treatment, we'll usually direct them to the National Institutes of Health."

Highly technical questions are referred to NASA's nationwide network of Industrial Application Centers (IACs), university-based facilities that have access to the massive RECON database, where results of all NASA research are stored. The database contains 100 million documents covering every area of aerospace activity, plus the continually updated, selected contents of some 15,000 scientific and technical journals.

"The IACs perform in-depth RECON searches tailored to the client's application," explained Heiland. "We provide a list of addresses for the ten IACS and brief descriptions of each center's function. Interested parties can then contact the IAC that best matches their needs."

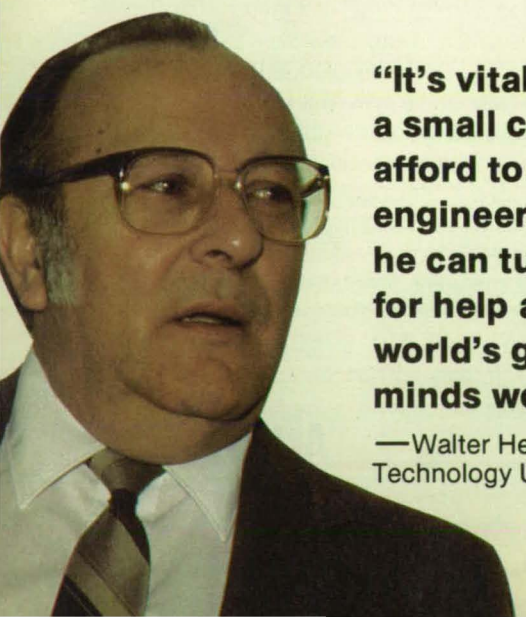
Fast Delivery

Each year Heiland's group processes about 100,000 requests for Technical Support Packages (TSPs)—packets of additional information on articles appearing in *NASA Tech Briefs*—which requires the reproduction of more than 1.5 million pages of technical reports. Despite this enormous influx, the TU Office has no backlog of TSP requests, according to Heiland. "The information is usually mailed out within two to four days of our receiving the request," he said proudly.

The office has in stock more than 8,000 support packages dating back as far as 1963. "If someone wants an update on an old TSP, we'll try to find out what's new in that area of technology," said Heiland. "We search our databank for updated reports or contact the Technology Utilization Officer at the appropriate NASA center to see if work has been done to bring the old technology up to par."

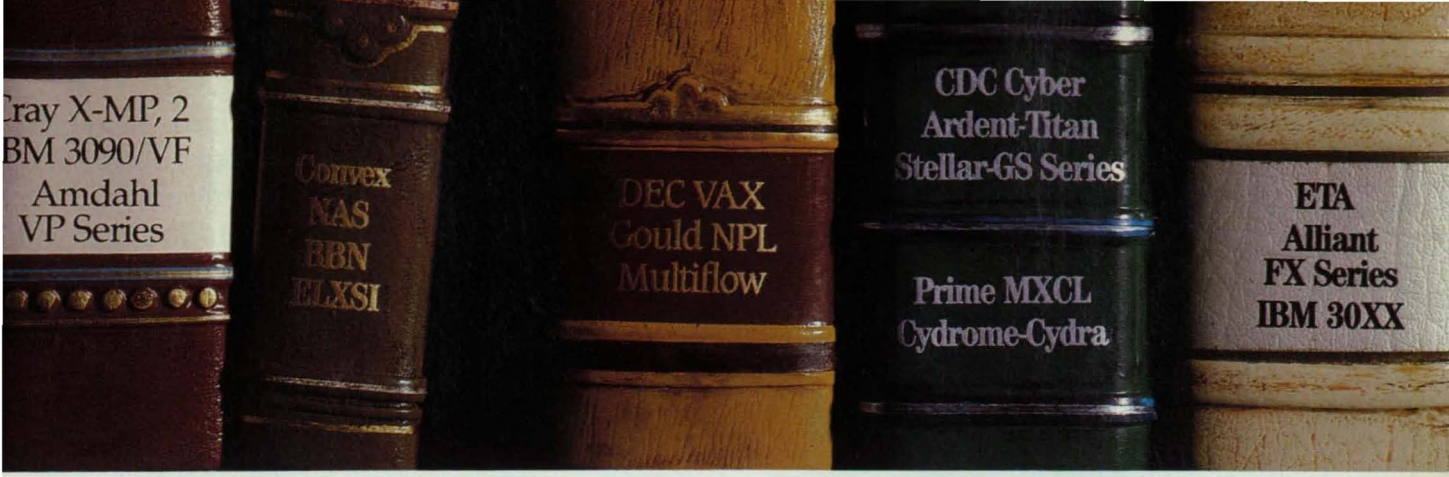
Space Program Dividends

Heiland's staff distributes a variety of NASA "special publications," including *Spinoff*, an annual report featuring commercially available products and services that have utilized NASA technology or assistance.

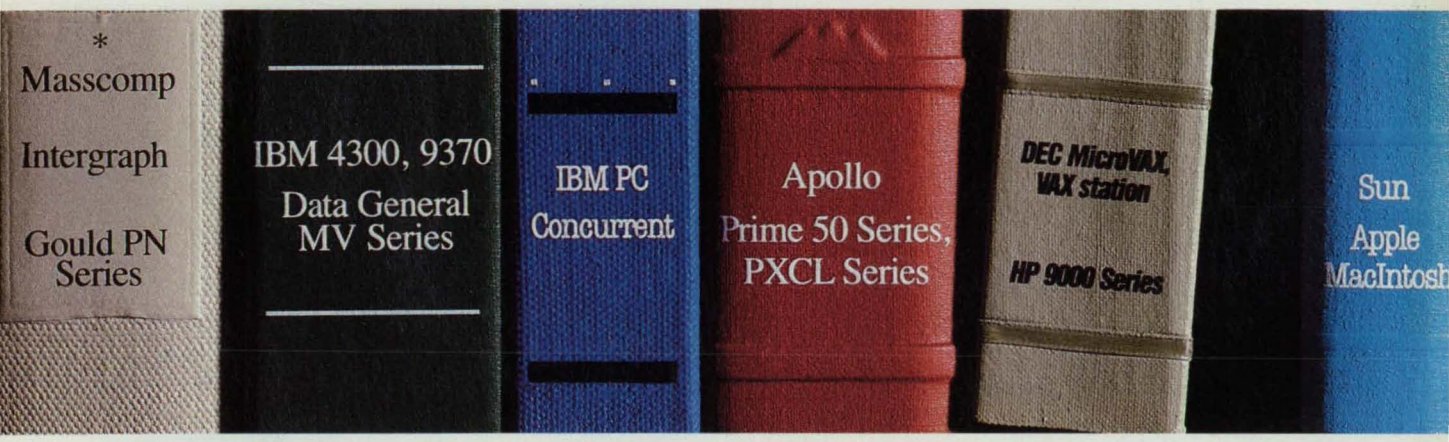


"It's vital that someone running a small company who can't afford to hire a staff of engineers is made aware that he can turn to the TU Program for help and have some of the world's greatest engineering minds working for him."

—Walter Heiland, Manager,
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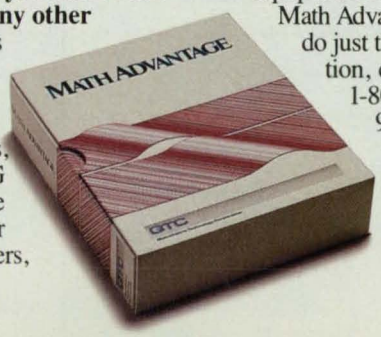


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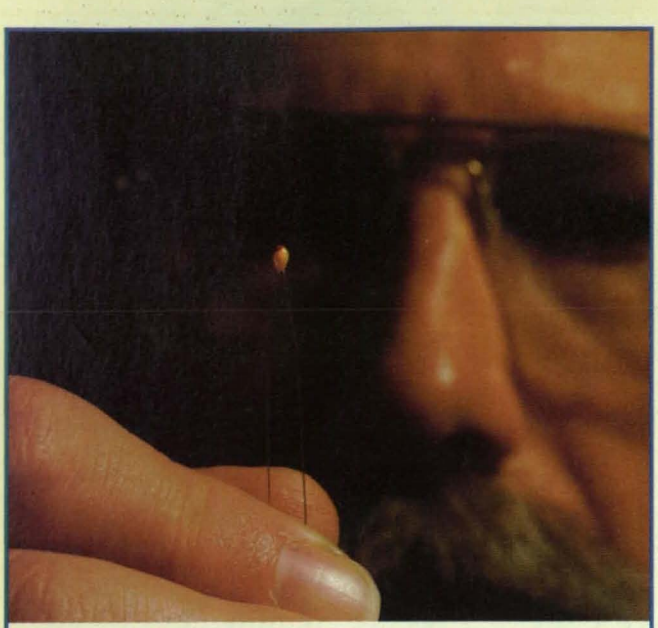
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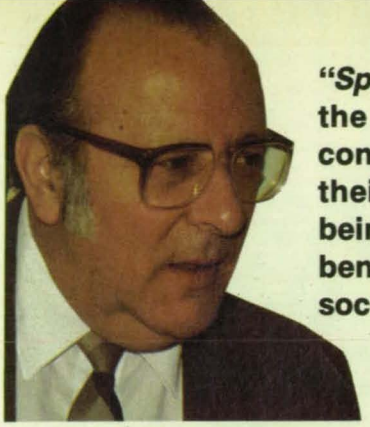
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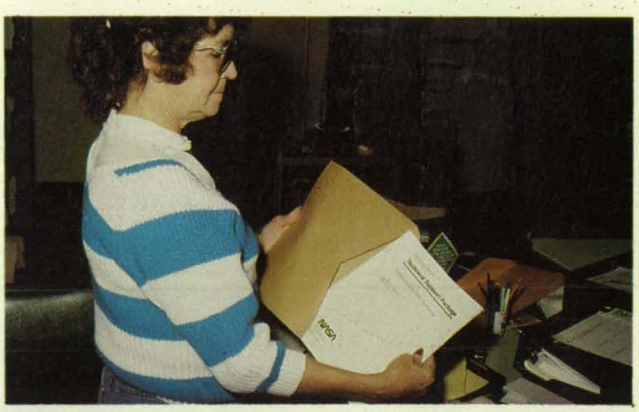


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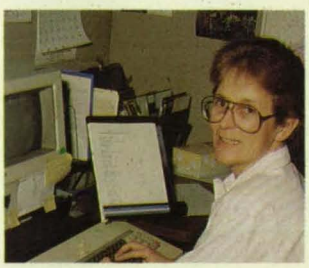
"*Spinoff* presents to the American public concrete proof that their tax money, part of which supports NASA's research and development efforts, is being used for the benefit of our entire society," Heiland commented.

Finding and researching new stories for *Spinoff* is another of the TU Office's responsibilities. "We really have to dig to unearth spinoffs," said Heiland. "Many companies are overly sensitive about revealing details on a product's development, and that hurts our chances of discovering a NASA connection."

By providing support for all elements of NASA's Technology Utilization Network, the TU office helps accelerate the transfer of aerospace technology to other sectors of the U.S. economy. The office's diverse responsibilities include:



Maintaining and mailing Technical Support Packages (TSPs)...



Developing reference and bibliographic information...



Processing information requests...



and managing the subscription list for NASA Tech Briefs.

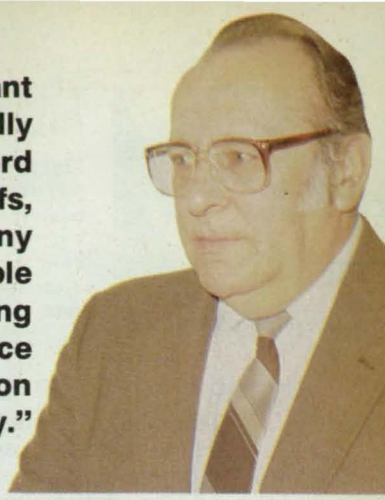
A larger problem, he said, is often engineers are not aware they have used NASA technology in creating a product. "They may not know the history of a technology. An engineer might apply a technique developed over 20 years ago for the Apollo Program to a new project he's working on, without knowledge of the NASA tie-in. That's why it's important we continually spread the word about spinoffs, educating as many people as possible to the far-reaching influence the space program has had on modern technology."

One way Heiland's team spreads its message is through public relations efforts with the media, supplying background literature on spinoffs to newspapers, magazines, and television stations across the country. In addition, they attend industry trade shows, sporting a giant booth display with examples of medical, consumer, and industrial spinoffs. And to help generate tomorrow's spinoffs, they often speak before various engineering associations at conferences and symposia, explaining how the NASA TU Network operates.



One of the many functions of the TU office: Research and preparation of camera-ready copy for the annual Spinoff publication.

"...It's important we continually spread the word about spinoffs, educating as many people as possible to the far-reaching influence the space program has had on modern technology."



"We believe in a hands-on approach to technology transfer," said Linda Watts, Supervisor of Spinoff and Space Benefits for the TU Office. "It's important that we get out of the office and meet with the public at trade shows and the like, in order to make them aware of the tremendous wealth of technology available to them through the NASA TU Program."

"It's vital that someone running a small company who can't afford to hire a staff of engineers is made aware that he can turn to the TU Program for help and have some of the world's greatest engineering minds working for him," Heiland said. "He can learn what research has been done in his area of interest and not have to reinvent the wheel." Mr. Heiland paused for a moment, and then added, "I think that's the most exciting thing in the world."□

The address and telephone number for the Technology Utilization Office at NASA STIF appear on page 18.

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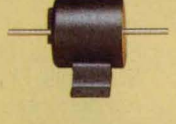
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New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 20). NASA's patent-licensing program to encourage commercial development is described on page 18.

Hybrid Infrared Imager

An experimental infrared imaging device combines an array of InSb photodetectors with an array of silicon FET switches. Promising to improve sensitive infrared cameras for astronomy, medicine, inspection, and surveillance, such a device exhibited a noise of only 950 electron charges and uniformity of responsivity among pixels differing by only eight percent.
(See page 23).

Acetylene-Terminated Aspartimides and Derived Resins

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(See page 40).

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(See page 78).

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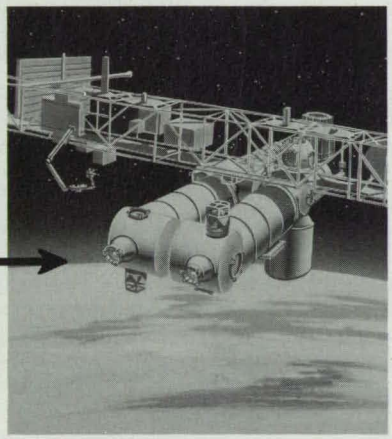
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We've outlined below NASA's TU Network—named the participants, described their services, and listed the individuals you can contact for more information relating to your specific needs. We encourage you to make use of the information, access, and applications services offered by NASA's Technology Utilization Network.

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How You Can Access Technology Transfer Services At NASA Field Centers:
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If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP). If a TSP is not available, you can contact the Technology Utilization Officer at the NASA Field Center that sponsored the research. He can arrange for assistance in applying the technology by putting you in touch with the people who developed it. If you want information about the patent status of a technology or are interested in licensing a NASA invention, contact the Patent Counsel at the NASA Field Center that sponsored the research. Refer to the NASA reference number at the end of the Tech Brief.

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Electronic Components and Circuits

Hardware Techniques, and Processes

19 Low-Power Magnetic Current Sensor
20 Microwave Comb Generator
21 Capacitive Displacement Sensor With Frequency Readout
21 Optimal Placement of Multiple Antennas
22 Power-Supply-Conditioning Circuit
23 Hybrid Infrared Imager
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Low-Power Magnetic Current Sensor

Direct current is sensed via a saturable-core reactor.

NASA's Jet Propulsion Laboratory, Pasadena, California

A transducer senses a direct current magnetically, providing isolation between the input and the output. The detecting-and-isolating element is a saturable reactor, in which the input current (that is, the current to be measured) passes through a one-turn control coil. The transducer provides an output of 0 to 3 Vdc for an input current of 0 to 15 Adc and consumes a power of 22 mW at 10 Adc input.

Line driver U_1 excites the saturable reactor L_1 by feeding a 2.3-kHz square wave through transformer T_1 (see figure). The output of L_1 is rectified by the bridge rectifier composed of diodes D_3 through D_6, then amplified by operational amplifier U_2, which has a gain of 20.

Diodes D_1 and D_2 commutate the reactive current fed back to the primary of T_1 from L_1. Without these diodes, large reactive voltage spikes on the primary would waste power and could destroy U_1. Filter capacitor C_1 stores the energy fed back through D_1 and D_2.

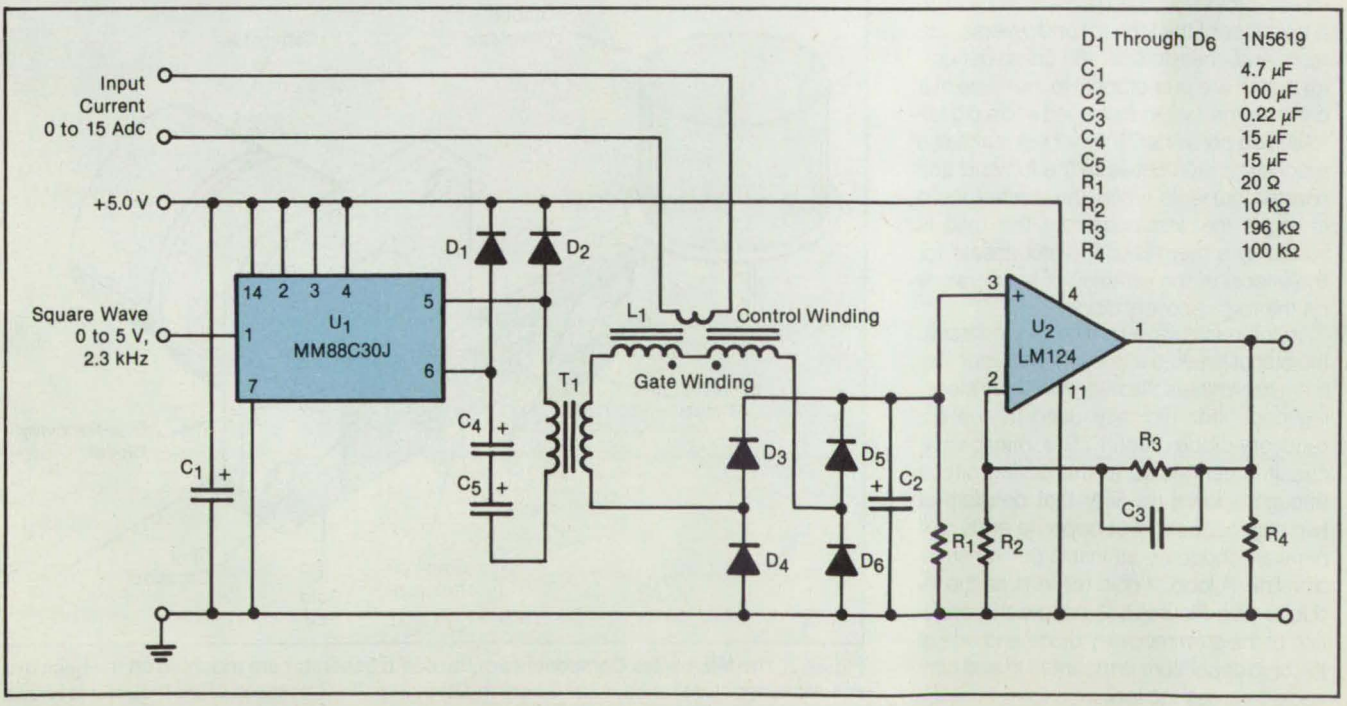
To minimize core losses, the core of T_1 is made of an alloy of 80 percent nickel/20 percent iron. To minimize capacitance, the primary and secondary windings are interleaved and progressively wound 350°. The primary and secondary windings consist of 408 and 660 turns, respectively, of No. 34 wire [6.3 mils (0.16 mm) in diameter].

The current in the gate windings of L_1 was specified to be 10 mA to keep the power consumption low. L_1 comprises two opposing gate windings of 1,500 turns each. To minimize capacitance, each was made by winding 750 turns of 350° progressively, applying insulation, then winding another 750 turns of 350° progressively rotated 180° from the first winding. The cores are matched and made of the same material as that of the core of T_1.

U_1 is a dual differential line driver that provides sufficient power to drive T_1. U_1, being a dual element, can be designed to self oscillate and not require synchronization at pin 1. If U, is used as an oscillator, then C_4 and C_5 can be omitted. U_2 was chosen because its input common-mode voltage includes ground and its output voltage can swing to ground during operation from a single power supply.

This work was done by Colonel W. T. McLyman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 92 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 18]. Refer to NPO-16888.



The **Low-Power Current Transducer** provides an output voltage of 0 to 3 Vdc nearly proportional to the input current of 0 to 15 Adc. Because the input is sensed magnetically, the output is electrically isolated from the input.

Microwave Comb Generator

Stable reference tones aid the testing and calibration of microwave receivers.

NASA's Jet Propulsion Laboratory, Pasadena, California

A signal generator puts out stable tones in the frequency range of 2 to 10 GHz at all multiples of a reference input frequency, which can be any frequency up to 1 MHz. Called a "comb generator" because its spectral plot resembles a comb, the circuit is used in testing microwave and spread-spectrum wide-band receivers. The design and physical configuration of the circuit result in a broad, relatively flat comb spectrum and high output.

The comb spectrum consists of the harmonics of the repetition frequency of the input pulses. The comb spectrum is generated in a step-recovery diode driven by a two-stage, high-speed amplifier (see Figure 1). The second stage of the amplifier acts as a switch that connects and disconnects a reverse-current source to or from the step-recovery diode. A smaller forward-current source is always connected to this diode, and when the reverse-current source is connected, it reverse-biases the diode to cause the step voltage recovery that generates the pulses. A Schottky diode on the output of the second amplifier stage keeps the output transistor from saturating when the step-recovery diode is turned off.

The forward and reverse current sources are provided by a dc bias circuit. The amplitudes of the forward and reverse currents and, therefore, of the comb-generator output are proportional to the value of a digital control word that is fed into a digital-to-analog converter. The dc bias maintains a constant ratio between the forward and reverse currents when the control word changes the amplitude, but the ratio is varied by a thermistor to compensate for the effects of the variation of temperature on the step-recovery diode.

In the microwave portion of the circuit, the output is taken across the inductor element to eliminate the need for the dc blocking capacitor typically used in a step-recovery-diode circuit. The microwave circuit is connected to the driving circuit through a low-pass filter that consists of two chip capacitors at opposite ends of a parallel-conductor, air-insulated transmission line. A loop of gold foil acts as the inductor (see Figure 2). A sandwich consisting of the step-recovery diode and one of the chip capacitors is mounted in and connected across the loop.

This work was done by E. H. Sigman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 57 on the TSP Request Card.* *NPO-17004*

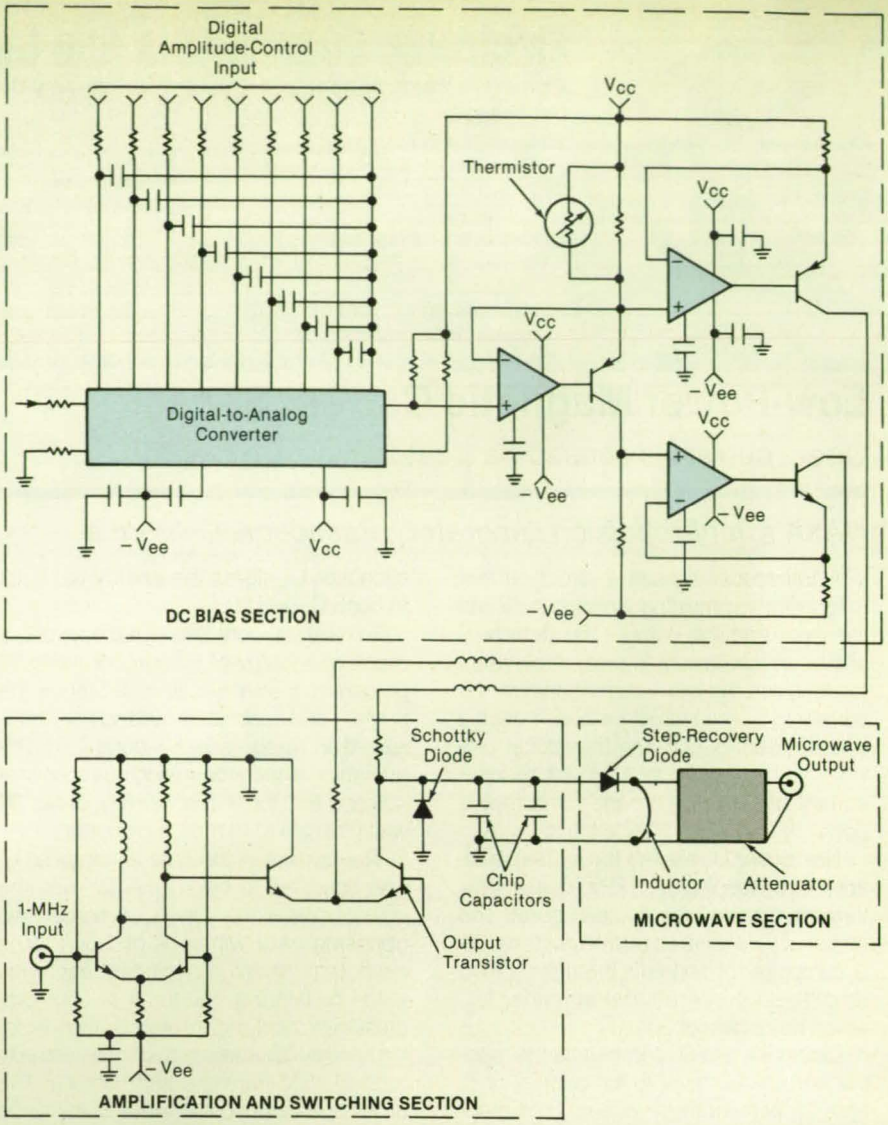


Figure 1. In the **Comb Generator**, a dc reverse-bias current is switched on and off at 1 MHz to generate sharp pulses in a step-recovery diode.

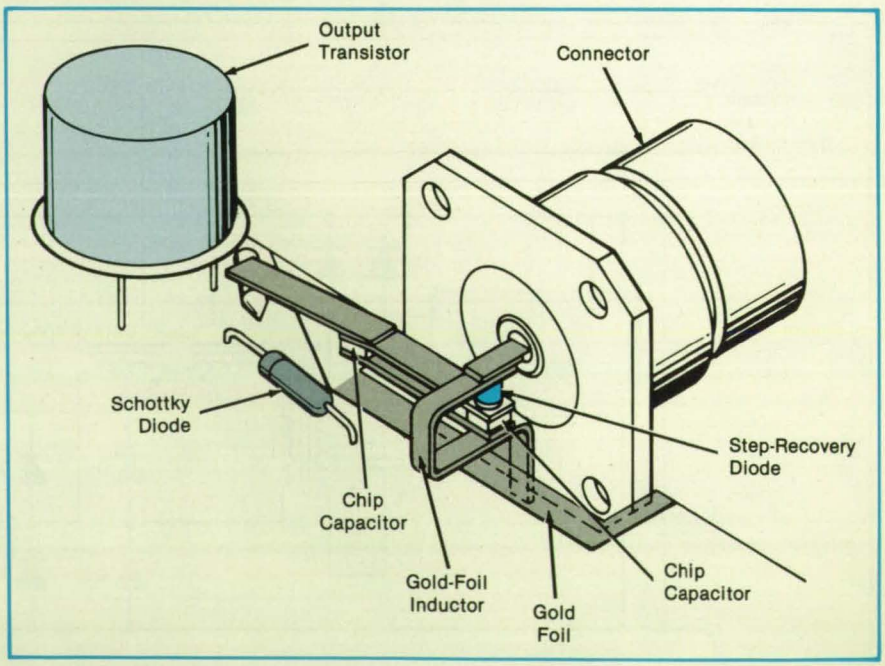


Figure 2. The **Microwave Components** of the comb generator are mounted on the back of a special connector that contains a built-in attenuator. The thickness of the inductor is shown exaggerated for clarity.

Capacitive Displacement Sensor With Frequency Readout

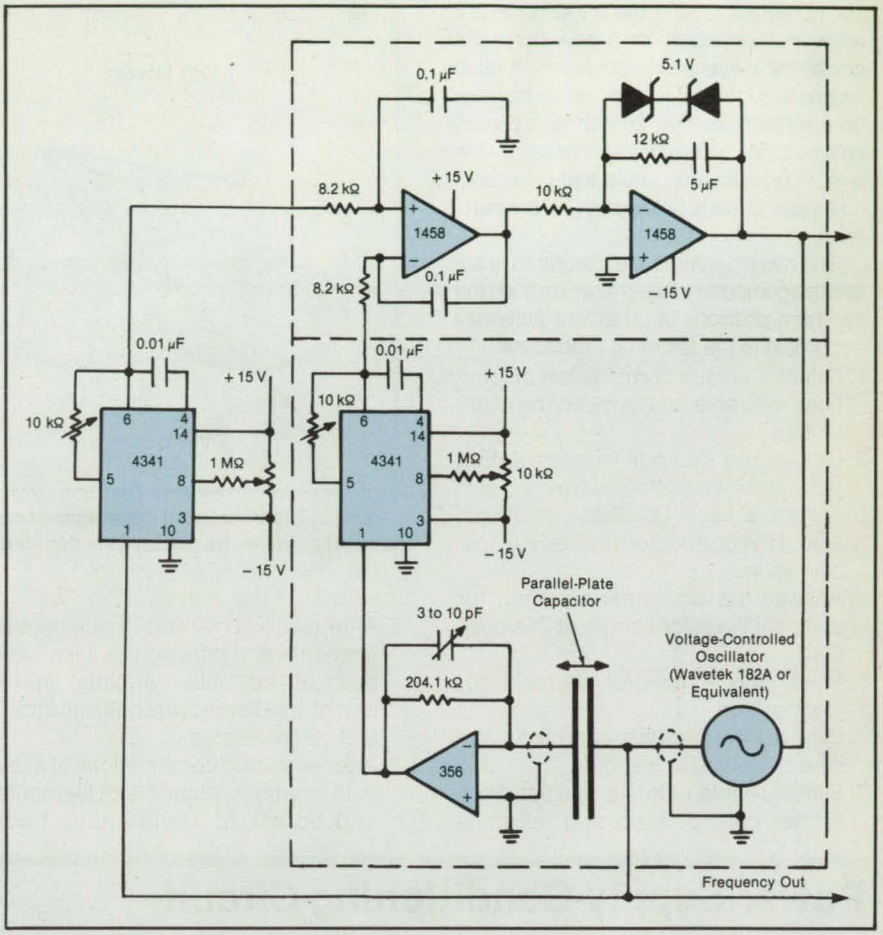
The frequency varies approximately linearly with displacement.

Lewis Research Center, Cleveland, Ohio

A simple displacement-measuring circuit senses the capacitance between two parallel conducting plates and produces an output signal, the frequency of which is proportional to the distance between the plates. Capacitive techniques are often used to measure displacements. For example, such methods have been used to measure the displacement of a pressure-sensing diaphragm and to control the separation of two mirrors in an optical interferometer. The displacement-sensing principle of this circuit provides advantages over other methods because of its frequency-encoded output and high linearity.

The parallel-plate capacitor is made part of an operational-amplifier differentiator circuit (see figure). A voltage-controlled oscillator applies a sinusoidal signal to the capacitor. The voltage that controls the oscillator is supplied by a servocontrol circuit, which acts to adjust the frequency of the oscillator so that the rms value of the output of the differentiator is held fixed. This, in turn, causes the frequency of the oscillator to be proportional to the distance between the plates. With plates 25 mm in diameter, a linearity of 0.2 percent of full scale and a resolution of 10 nm were obtained for plate separations ranging from 0 to 5 mm.

This work was done by Klaus Fritsch of John Carroll University for **Lewis Research Center**. *No further documentation is available.*
LEW-14792



The **Frequency of the Voltage-Controlled Oscillator** is nearly proportional to the distance between the plates of the parallel-plate capacitor for displacements up to 5 mm.

Optimal Placement of Multiple Antennas

Obscuration by the structure or vehicle is taken into account.

Lyndon B. Johnson Space Center, Houston, Texas

A computer program based on a pair of algorithms selects approximately optimal locations of antennas and the approximately optimal number of elements in each antenna of a multiple-antenna communication system. Developed to aid in the design of the antenna system of a conceptual space station, the algorithms could also be applied to such a system aboard a ship or aircraft, on a building in a city, or in any location where transmission and reception are blocked in some directions from each potential antenna-mounting point.

The problem is to provide the required directional coverage of antenna radiation patterns with the minimum number of antenna elements. One way to solve this problem is to select the desired antenna positions, then compute and compare the directional coverages provided by all possible combinations of numbers of antenna elements and boresight angles (nominal aiming directions). This "brute-force" approach is exact but requires astronomical amounts of computing time in all but the simplest cases. The new program sacrifices some accuracy to yield solutions with a reasonable amount of computation.

The first algorithm begins with the analysis of the directions of obscuration at a given antenna position (see Figure 1). On the basis of the amount and direction of obscuration, the algorithm selects an initial boresight angle. Then, making an assumption about the radiation pattern of each element and the orientations of elements relative to each other, it computes the directional coverages of combinations

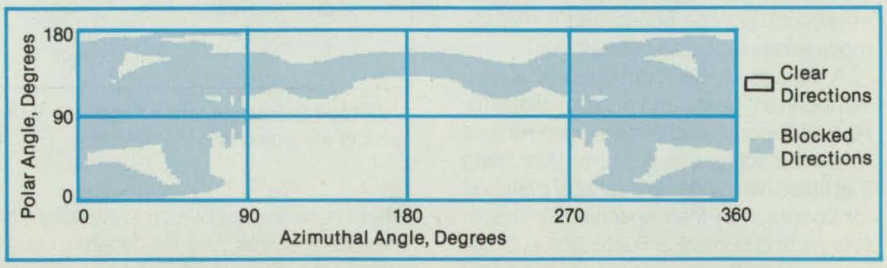


Figure 1. The **Obscuration in the Field of View** at a given antenna location is taken into account in the choice of the number of antenna elements to be mounted there.

of different numbers of elements (see Figure 2). Next, using a cost-versus-benefit function supplied by the user, the algorithm selects the number of elements to provide the best overall antenna-gain pattern in the unobscured directions.

The second algorithm begins by moving the boresight around the initial boresight angle in the search for a new boresight angle that yields better coverage. If such an angle is found, it is selected as the new boresight angle. The search is repeated until no other boresight yields better coverage. In practice, the angle that gives best coverage is usually found in a few iterations.

The two algorithms are integrated to obtain the computer program, which finds the optimum positions of up to four antennas according to the following procedure:

1. Select a unique combination of locations available for the mounting of antennas.
2. Obtain the composite obscuration pattern for this combination.
3. From the list of available positions, select the one that offers the least obscuration.
4. Analyze the obscuration pattern for an initial boresight angle at this position.
5. Select the number of elements for this position.
6. Perform the iterative search for the best boresight angle.
7. Eliminate this antenna position from further consideration and return to step 3.
8. After all combinations of numbers of elements and boresight angles have been tested, obtain another unique set of available antenna locations and return to step 2.
9. After all unique combinations of available locations, numbers of elements, and boresight angles have been tested, select the one that yields the maximum coverage.

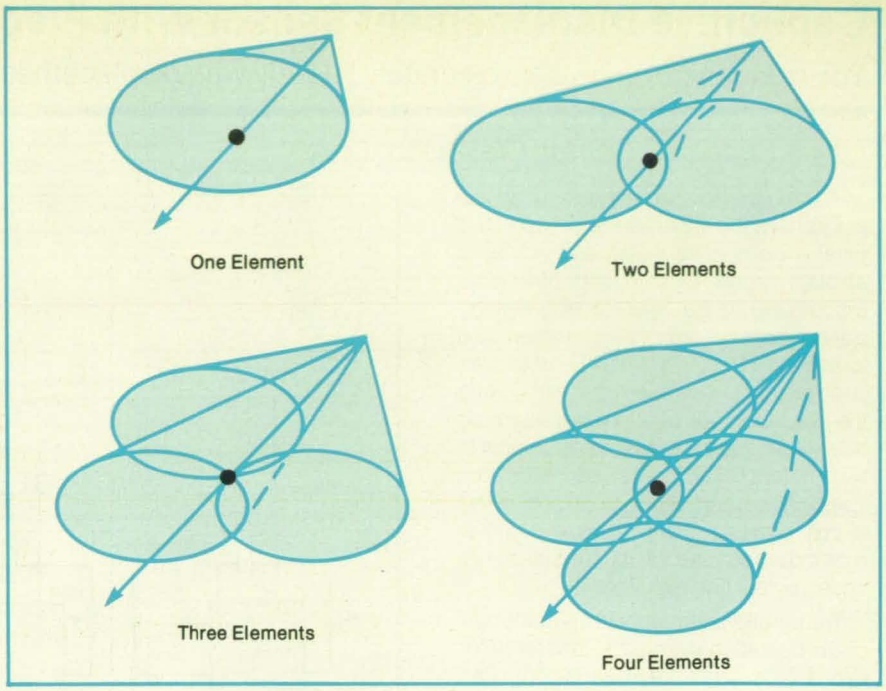


Figure 2. The **Directional Coverages** of combinations of as many as four antenna elements are computed in the search for a combination to cover the clear portion of the field of view.

This work was done by Kyle W. Shelton, Y. C. Loh, and K. Tu of Lockheed Engineering and Management Services Co. for **Johnson Space Center**. *For further information, Circle 158 on the TSP Request Card.*

MSC-21291

Power-Supply-Conditioning Circuit

Fluctuations of voltage are suppressed in power supplies for precise radio-frequency circuits.

NASA's Jet Propulsion Laboratory, Pasadena, California

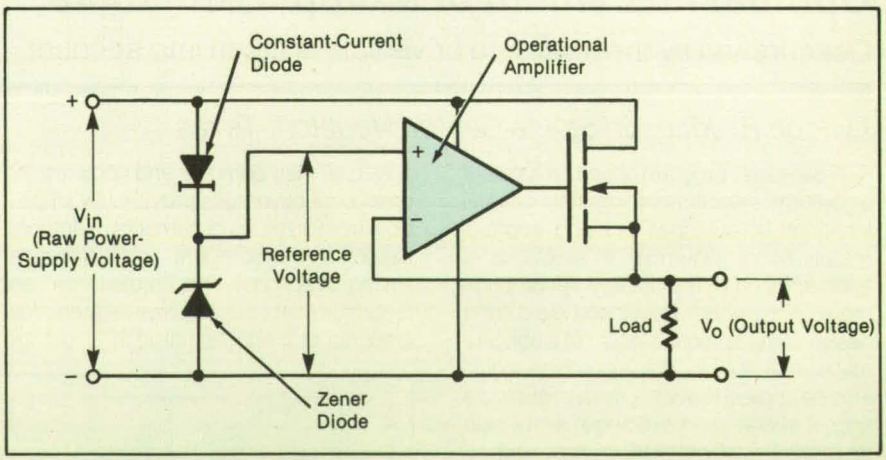
A power-supply-conditioning circuit suppresses both periodic and random deviations of dc supply voltage from the desired steady level. Essentially a highly-stable feedback voltage regulator, the conditioner is intended for use in conjunction with a conventional power-supply circuit to provide a more nearly constant voltage to an atomic frequency standard or other precise oscillator. Without such conditioners, the outputs of most commercial power supplies contain fluctuations that cause unacceptably-large phase and amplitude modulation of precise oscillators.

A voltage divider consisting of a constant-current diode and a Zener diode (or several Zener diodes in series) generates a reference voltage (see figure). Assuming that these two diodes are suitably matched for operation in their specified ranges of voltage and current, a fluctuation e_i of the input voltage V_{in} is suppressed in the output of the voltage divider by a rejection ratio of

$$e_o/e_i = r_z/(r_c + r_z)$$

where e_o = the fluctuation in the output of the voltage divider, r_z = the dynamic resistance of the Zener diode, and r_c = the dynamic resistance of the constant-current diode. Representative values of r_z and r_c are 15 Ω and 50 kΩ, respectively, yielding a rejection ratio of about 3×10^{-4}.

The voltage reference operates at low current — typically, a few milliamperes.



A **Voltage Reference and a Feedback Voltage Follower** are combined to suppress fluctuations in the power-supply voltage.

The rest of the circuit acts as a voltage follower; that is, a buffer between the high-impedance, low-current voltage reference and the high-current (typically as much as several amperes), low-impedance output. Feedback through the operational amplifier regulates the current through the field-effect transistor to reproduce the reference voltage at the output. With the proper selection of components, the voltage follower does not degrade the overall rejection ratio significantly.

The basic circuit concept can be varied to suit a given situation. For example, two such circuits can be concatenated to suppress fluctuations even further, and resistors and bypass capacitors can be added or deleted at various locations. A single-stage conditioner was built and tested by adding an alternating voltage to the raw power-supply voltage and measuring the alternating voltage at the output. The rejection ratio was found to vary from 73.5 dB at a frequency of 1 kHz to 51 dB at 10 kHz.

This work was done by L. E. Primas and R. C. Loveland of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 89 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 18]. Refer to NPO-17233.

Hybrid Infrared Imager

An experimental device has low noise and high uniformity.

NASA's Jet Propulsion Laboratory, Pasadena, California

An infrared imaging device combines an array of InSb photodetectors with an array of silicon field-effect-transistor (FET) switches. The InSb chip forms a roof over the Si chip, each InSb detector cell engaging an indium bump on the corresponding Si switch cell below it. As the FET switches in the 128-by-128 array turn on in sequence, they read out the charges on the 128-by-128 array of photodetectors and multiplex them in a serial output that represents the pattern of light on the array of photodetectors.

When fully developed, the double-chip device will be useful in sensitive infrared cameras for astronomy, medicine, inspection, and military surveillance. It can read out image data at rates up to 10 MHz and can readily be expanded to a 256-by-256 array.

The multiplexer chip is 0.4 in. (1 cm) square. The detector chip is 0.3 in. (0.76 cm) square. The pixels measure 50 μm square, and their centers are spaced 60 μm apart. The assembled chips are housed in a 3/4- by 3/4- by 1/8-in. (1.9- by 1.9- by 3.2-mm) package.

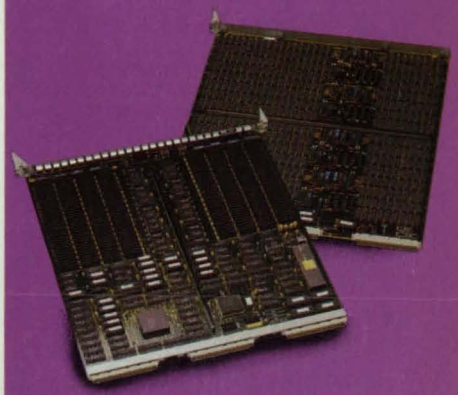
The multiplexer chip is first bonded to a ceramic carrier for processing. The carrier also serves as a base for the package. Indium bumps are plated on the switch cells photolithographically. A similar set of indium bumps is plated on the photodetector cells (see figure), from the same photolithographic mask, to ensure precise registration with the bumps on the multiplexer.

The detector chip is placed on the multiplexer chip, bump to bump. Pressure and heat are applied so that the bumps bond together. The outer surface of the InSb chip

Indium Bumps on an array of InSb photodetectors mate with similar bumps on the multiplexer. The rough texture of the bumps increases the contact area.



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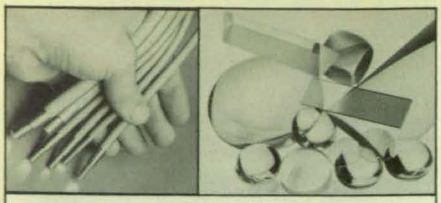
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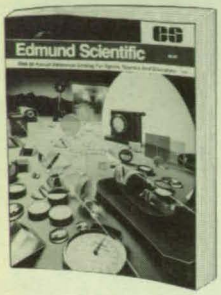


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(which is the substrate of the array of photodiodes) is polished to reduce its thickness to 10 μm, enabling it to transmit light more efficiently to the photodiode junctions. Plans call for further reductions of the thickness to only 5 μm.

When tested at a temperature of 80 K, the assembled device exhibited a noise of only 950 electron charges. The uniformity of responsivity differed among pixels by only 8 percent. The nonuniformity of dark current was even smaller — only about 5 percent.

This work was done by Gary C. Bailey of Caltech for ***NASA's Jet Propulsion Laboratory****. For further information, Circle 55 on the TSP Request Card.*
NPO-17218

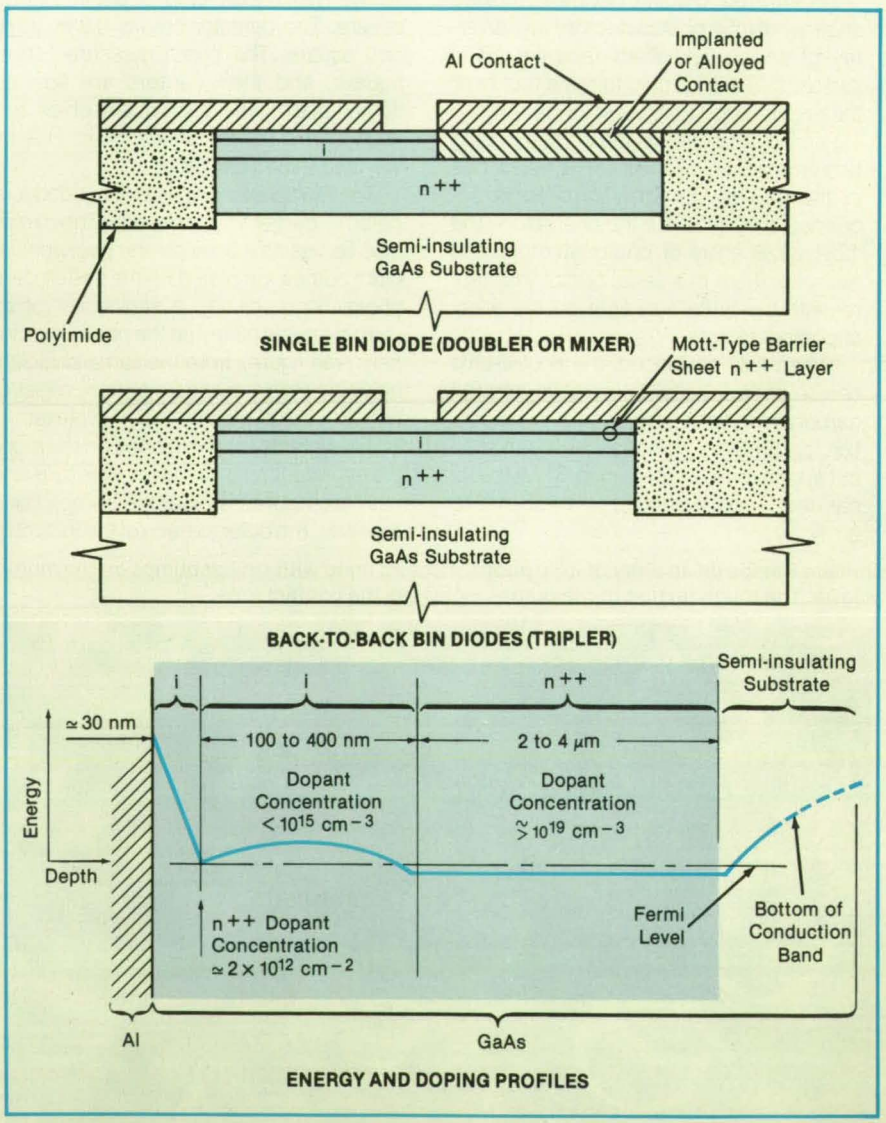
BIN Diode for Submillimeter Wavelengths

Uses would include mixers and harmonic generators in receivers for atmospheric and space spectroscopy.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed diode structure comprising barrier/intrinsic/n^+ (BIN) semiconductor layers should be useful for the generation of harmonics or for heterodyne mixing in receivers for atmospheric and space spectroscopy operating at millimeter and submillimeter wavelengths. Used as frequency doublers or triplers, diodes of the new type would extend the frequency range of present solid-state oscillators (e.g., GaAs Gunn diodes). Although highly efficient and tunable, such oscillators are currently limited to frequencies below about 100 GHz.

The proposed diode (see figure) would



The **BIN Diode** can be produced in various configurations: a single diode for use as a frequency doubler or mixer or a pair of diodes back-to-back for a frequency tripler. Also shown are the energy and doping profiles of the diode.

be formed by selective doping during epitaxial growth, starting with a semi-insulating substrate. The use of high-mobility semiconductors like GaAs would extend the cutoff frequency. Either molecular-beam epitaxy (MBE) or organometallic chemical-vapor deposition can be used to form the layers of the diode. A planar growth process (e.g., MBE) would permit subsequent fabrication of arrays of diodes by standard photolithographic techniques, to achieve quasi-optical coupling of submillimeter radiation.

The new diode structure would overcome difficulties encountered in the fabrication of a recent thin metal-oxide/silicon (T-MOS) design. Both the BIN and the T-MOS devices would be much more efficient than the GaAs Schottky diodes currently used to generate harmonics. Unlike the T-MOS structure, the BIN diode would require no insulator layer but instead would rely on a Mott-type barrier formed in the semiconductor by selective doping. In addition, the intrinsic layer of the BIN diode would provide an active space-charge-limited region that would result in enhanced nonlinearities in the dependence of the capacitance upon voltage (especially at reduced operating temperatures) and minimize the resistance•capacitance time constant to maximize the cutoff frequency.

The back contact of the BIN diode would be a heavily negatively doped (n^{++}) layer, 2 to 4 μm thick. A 100- to 400-nm-thick intrinsic or undoped intrinsic (i) layer would provide the space-charge-limited region. An n^{++} sheet of dopant with a density•thickness product of about 2×10^{12} atoms/cm^2 would terminate the Mott-type barrier formed between the intrinsic layer and the aluminum front contact. This sheet should be as thin as possible (<2 nm) for optimum performance.

This work was done by J. Maserjian of Caltech for ***NASA's Jet Propulsion Laboratory****. For further information, Circle 68 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 18]. Refer to NPO-17258.

Testing Fixture for Microwave Integrated Circuits

Devices can be characterized repeatably and nondestructively.

Lewis Research Center, Cleveland, Ohio

A testing fixture facilitates the radio-frequency characterization of microwave and millimeter-wave integrated circuits. The fixture is intended to be used in conjunction with an automatic network analyzer to provide the user with deembedded scattering parameters of the device under test. The fixture has been demonstrated to operate from 26.5 to 40.0 GHz, and operation can be extended to much higher frequencies.

Previous fixturing techniques have employed various styles of transitions from test-system transmission media to the device under test, each such technique possessing some favorable attributes as well as significant limitations. These limitations include nonrepeatability, complexity, and narrow bandwidth. In addition, these techniques are often destructive to the devices and tend to be labor-intensive. Furthermore, no known existing test fixture permits chip-level characterization above 26.5 GHz.

In an effort to enhance the performance of the new fixture, the number of its components was minimized. The fixture includes a base onto which two cosine-tapered ridge waveguide-to-microstrip transitions are fastened (see figure). The length and profile of the taper have been determined analytically to provide maximum bandwidth and minimum insertion loss. Each cosine taper provides a transformation from high impedance of the waveguide to the characteristic impedance of the microstrip.

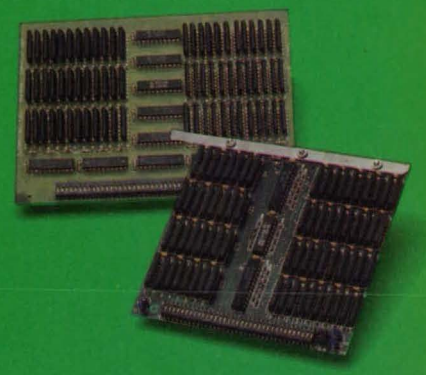
The integrated circuit is mounted on a customized carrier, which is inserted between the bottom of the ridge and the base of the waveguide. The electric field is concentrated by the ridge and launched onto the microstrip via direct pressure contact. The carrier provides isolation between the device under test and the test fixture as well as bias-control circuitry. Control voltages are applied to the carrier by use of a self-aligned bias module with integral spring-loaded contacts.

A "through, short, delay" calibration algorithm is used to extract the scattering parameters of the device. The basic calibration establishes an ancillary reference plane that subsequently can be shifted to the terminals of the device.

The unique features of this fixturing technique include the following:

- Operation is over the full bandwidth of the waveguide.
- The system is characterized at the level of the chip at millimeter wavelengths.
- Nondestructive contact is made to the carrier for both radio-frequency and direct-current connections.

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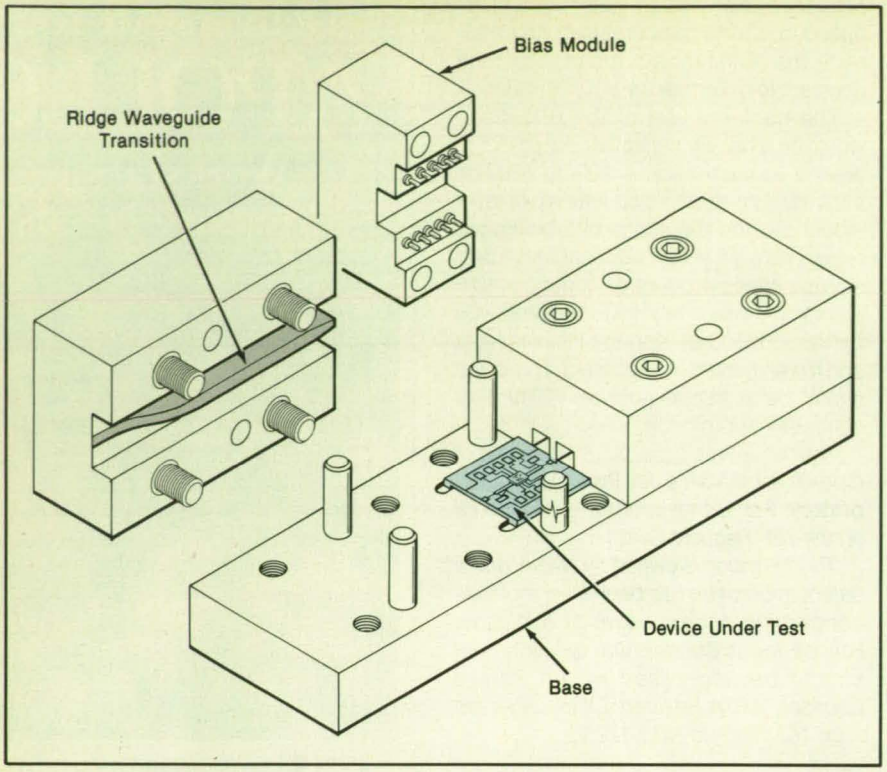
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The **Testing Fixture** for microwave integrated circuits provides improved contact, repeatability, matching of impedances, and nondestructive mounting of the device under test.

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- Only one set of calibration standards is required, regardless of the size of the die.
- Calibration coefficients are transferred to the network analyzer so that radio-frequency measurements can be viewed in "real time."
- All network-analyzer features are maintained.
- The software is independent of frequency.

This work was done by Robert Romanofsky and Kurt Shalkhauser of **Lewis Research Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center [see page 18]. Refer to LEW-14746.

Books and Reports

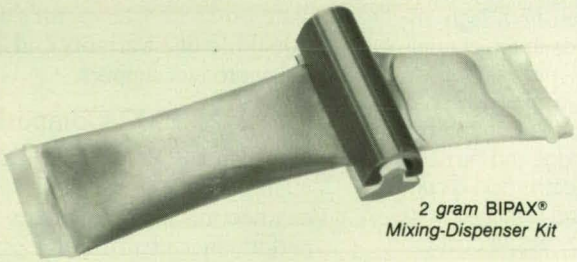
These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Trends in Susceptibility to Single-Event Upset

Data are compiled from several sources.

A report provides a nearly comprehensive body of data on single-event upsets

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due to irradiation by heavy ions. The report combines new test data and previously published data from governmental and industrial laboratories. Clear trends that emerge from the data should be useful in predicting the future performances of devices.

The data are arranged in two tables. Table 1 lists data for 104 metal-oxide/semiconductor (MOS) and metal-nitride-oxide/semiconductor (MNOS) integrated circuits. Table 2 gives data for 82 bipolar integrated circuits.

Each circuit is described by function, fabrication technology, manufacturer, testing organization, number of bits or gates, linear energy transfer threshold, device upset cross section, and upset cross section per bit. A remarks column notes the presence of latchup and anomalies.

The most important fact that emerges from the tabulated data is that most of the MOS devices [except negatively-doped-channel MOS (NMOS) devices] are less susceptible to single-event upset than are other types of devices. Almost all the bipolar devices, except logic devices of the 54XXX family, are more susceptible.

Both complementary metal-oxide/semiconductor (CMOS) and bipolar read-only memories (ROM's), including programmable ROM's, are subject to apparent upsets even though they have no circuit elements with bipolar states. Radiation-hardened parts (resistant to high total doses) are sometimes more resistant to single-event upsets.

Electrically alterable ROM's made by MNOS technology are not subject to soft errors, but they may be permanently damaged by heavier ions. The probability of damage increases with the frequency of erasing and writing because permanent damage can occur only when a high electric field is present in the gate insulator.

This work was done by Donald K. Nichols and William E. Price of Caltech, Wojciech A. Kolasinski and Rukotaro Koga of The Aerospace Corp., Alvin E. Waskiewicz of Rockwell International Corp., and James C. Pickel and James T. Blandford of IRT Corp. for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Trends in Parts Susceptibility to Single Event Upset From Heavy Ions," Circle 128 on the TSP Request Card.*
NPO-17147

Spread of Charge From Ion Tracks in Integrated Circuits

Single-event upsets spread to adjacent memory cells.

Single-event upsets (SEU's) — which are reversible changes in logic states, caused by impacts of heavy ions — can propagate to adjacent cells in integrated memory circuits. This is one of the findings of experiments in the lateral transport of electrical-charge carriers from ion tracks in 256K dynamic random-access memories (DRAM's). As the dimensions of integrated circuits decrease, the vulnerability to SEU's increases. The understanding gained through this and future studies may enable the design of less vulnerable circuits.

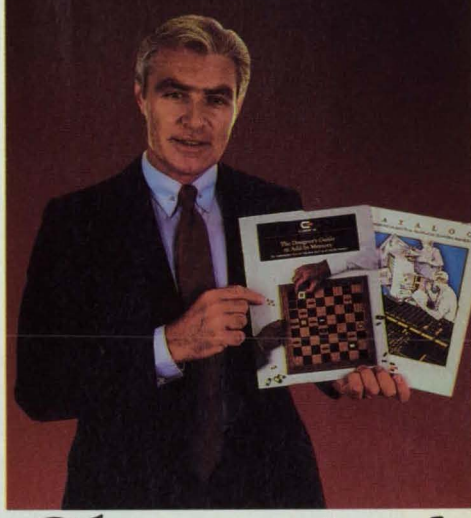
An energetic ion that strikes an integrated-circuit chip perpendicularly to its surface produces electrons and holes along the ion track. If the track intersects a charge-collecting junction, some of the charge is collected promptly along the track with the help of electric-field-funnel transport. However, if the track is longer than a few microns, the electric field is restored to its original configuration (the funnel collapses) before all the charge is collected, leaving the remaining charge to diffuse outward from the track in all directions. Furthermore, if the ion track does not intersect a charge-collecting junction, nearly all of the charge diffuses outward.

The portion of the charge that diffuses to (or along) the surface of the chip can be captured by other charge-collecting junctions, possibly causing SEU's in the memory cells containing those junctions. DRAM's are particularly suitable for measurements of this phenomenon, because maps of bit errors around ion tracks in these circuits are direct indications of which memory cells have received at least the critical charge, Q_C, for SEU. For example, in one experiment, bit errors occurred in a cluster of eight memory cells, one of which was struck by a 168-MeV bromine ion. This is consistent with independent measurements that show that the cross section for SEU by a 168-MeV bromine ion is eight times the area of one cell in the particular memory circuit.

The critical charge of a DRAM cell is given by $Q_C = C(V_{DD} - V_B)$ where C = the cell storage capacitance, V_{DD} = the supply voltage, and V_B = the input bias voltage of the sensing amplifier. Thus, the vulnerability of the cells to SEU can be increased or decreased by adjustment of V_{DD} or V_B. This makes it possible to extract more information from ion-impact tests by expanding or shrinking clusters of bit errors around a single ion track or by inferring a "gray-scale" map of the charge distribution about a single track from measurements about multiple tracks.

This work was done by John A. Zoutendyk, Harvey R. Schwartz, and R. Kevin Watson of Caltech, and Leland R. Nevill of Micron Technology, Inc., for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Lateral Charge Transport From Heavy-Ion Tracks in IC Chips," Circle 118 on the TSP Request Card.*
NPO-17265

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Improved Bipolar Separator for Lead Acid Batteries

The new separator would prolong battery life.

A new design for a bipolar separator would consist of a polyethylene plate 0.01 in. (0.25 mm) thick and glass mats 0.01 in. (0.25 mm) thick, bonded to both faces of the plate. Loosely woven scrims of chemical glass 0.01 in. (0.25 mm) thick, bonded to the glass mats, hold the active material. The glass mats and the scrims are attached by glue. The new separator design would reduce the loss of the active material, thus prolonging battery life.

This work was done by Wally E. Rippel and Dean B. Edwards of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 74 on the TSP Request Card.*

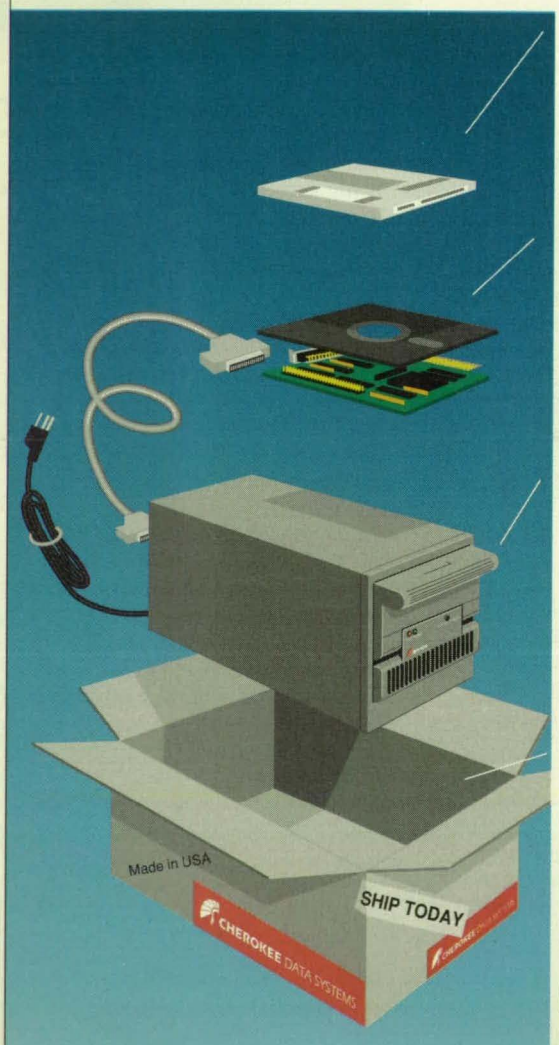
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Endurance Tests of Amorphous-Silicon Photovoltaic Modules

Failure mechanisms in high-power service are studied.

A report discusses the factors that affect the endurance of amorphous-silicon solar cells. The report is based on field tests and accelerated aging of photovoltaic modules. The report concludes that aggressive research is needed if amorphous-silicon modules are to attain a 30-year life — the value that the U.S. Department of Energy has established as a goal for photovoltaic modules in commercial energy-generating plants.

Research topics of high priority include the following:

- Defects induced by light that degrade the outputs of photovoltaic cells;
- Corrosion of cells and the increased series resistance that results;
- The breaking strength of glass for large modules; and
- The development of protective encapsulants to prevent weathering and maintain high-voltage isolation.

Amorphous-silicon modules from leading manufacturers were subjected to standard qualification tests. They were also aged in the field under ambient conditions and at fixed temperatures of 70, 85, and 100 °C. They were given long-term tests at a temperature of 85 °C and relative humidities of 5 and 85 percent with various bias voltages, and they were subjected to laboratory tests for hotspots and corrosion. The overall method followed that developed earlier for crystalline-silicon modules. The researchers found that although the qualification tests for crystalline-silicon modules are useful, they do not excite the principal mechanisms that degrade amorphous-silicon modules.

The following failure mechanisms were evaluated: open circuits between cells, short-circuited cells, effects induced by light, gradual loss of power in cells, optical degradation of modules, front-surface soiling, breakage of glass in modules, open circuits between modules, hotspots in modules, failures of bypass diodes, short circuits between modules and ground, and delamination of modules.

This work was done by Ronald G. Ross, Jr., and Russell S. Sugimura of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Long-Term Experimental Testing of Silicon Modules," Circle 8 on the TSP Request Card.*
NPO-17304

Electronic Systems

Hardware Techniques, and Processes

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31 Design and Analysis of Optical Communication Links

32 Photovoltaic Generation of Power by Utilities

Processing SAR Images on Board

Images would be produced faster, and data-transmission requirements would be reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed synthetic-aperture radar (SAR) processor would operate aboard the moving radar platform, turning the raw signal data into images of the scanned terrain. In conventional SAR systems, the raw data are either transmitted to stations on the ground or else recorded on magnetic tape by high-density digital recorders (HDDR's) for subsequent processing on the ground. The principal advantages of the proposed system are that it would make SAR images available almost immediately and that the processed data to be transmitted or recorded would be only about one-fifth as voluminous as the raw data. Onboard image compression could reduce the volume of data even further.

The processor would generate four-look imagery from the raw data by use of a time-domain parallel-accumulator approach. In most SAR processors, the correlation of the radar signals with the range response functions is performed before the correlations with the azimuth response functions because doing so eases the flow of data and the correction for range migration. In this processor, the number of azimuth correlators (and, therefore, the power and weight of the system) would be reduced by performing the azimuth correlation first.

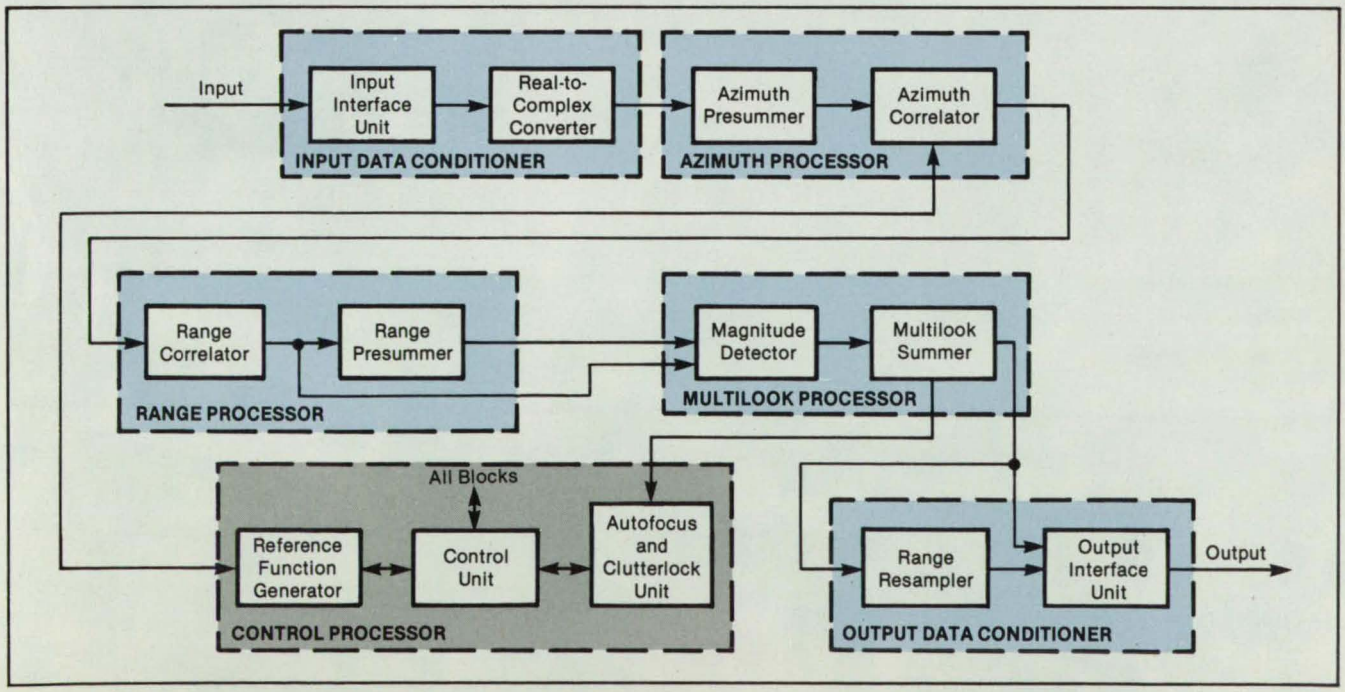
The six functional elements of the conceptual SAR processor are the input data conditioner, the azimuth processor, the range processor, the multilook processor, the output data conditioner, and the control processor (see figure). The control processor is connected to the other functional elements through a control bus.

The input data conditioner reduces the rate of the SAR echo data. It receives the raw digital SAR signal from a real-time radar source or from a HDDR on board. It synchronizes the echo and radar-pulse signals, extracts position and scanning information from the header on the raw data signal, and converts the input real data samples into complex-arithmetic samples for use by the azimuth processor.

The azimuth processor includes two single-look parallel modules, each of which consists of an azimuth presum filter and an azimuth correlator. Each presum filter applies a filtering operation to consecutive samples, then performs downsampling to reduce the data rate by a factor of 3. Each azimuth correlator removes the effect of range walk and range curvature, then performs the azimuth compression necessary to achieve the desired azimuth resolution.

Each of the two azimuth outputs is sent to one of two modules in the range processor. Each module contains a range correlator, which performs the range compression necessary for the desired range resolution. At high look angles, the range-correlator output is sent through the range presummer, which extracts two range looks and feeds the results to the multilook processor. At low look angles, the output of the range correlator is divided into two subswaths and sent directly to the multilook processor.

The multilook processor includes the magnitude detector, which detects the complex magnitude of the correlated data.



The **Onboard SAR Processor** would form images of the scanned terrain, thereby reducing the amount of data to be stored or transmitted.

It also includes the multilook summer, which incoherently sums all range and azimuth single-look data to obtain the multilook images.

The output data conditioner consists of the range resampler and the output interface unit. At low look angles, where the range pixel spacings are finer than required, the conditioner reduces the output pixel spacings so that the number of samples per range line can be kept constant. At high look angles, the output of the multilook summer is sent to the output interface unit directly, bypassing the range resampler. The output interface unit merges the output-header and synchronization-code information with the processed images from either the range resampler or the multilook summer (depending on look angles).

The control processor consists of the autofocus and clutterlock unit, the reference-function generator, and the control unit. The autofocus and clutterlock unit tracks the Doppler frequency and the change in the rate of change of the Doppler frequency from the multilook data. The reference-function generator generates the azimuth reference function needed for azimuth compression, based on the Doppler parameters received from the control unit. The control unit generates the processor-configuration-control information and the range reference function based on the received header data. It also estimates the new Doppler frequency and the rate of change of the Doppler frequency, based on the data received from the autofocus and clutterlock units.

This work was done by Kuang Y. Liu and Wayne E. Arens of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 159 on the TSP Request Card.*
NPO-17195

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Terrain-Following/Terrain-Avoidance System for Helicopters

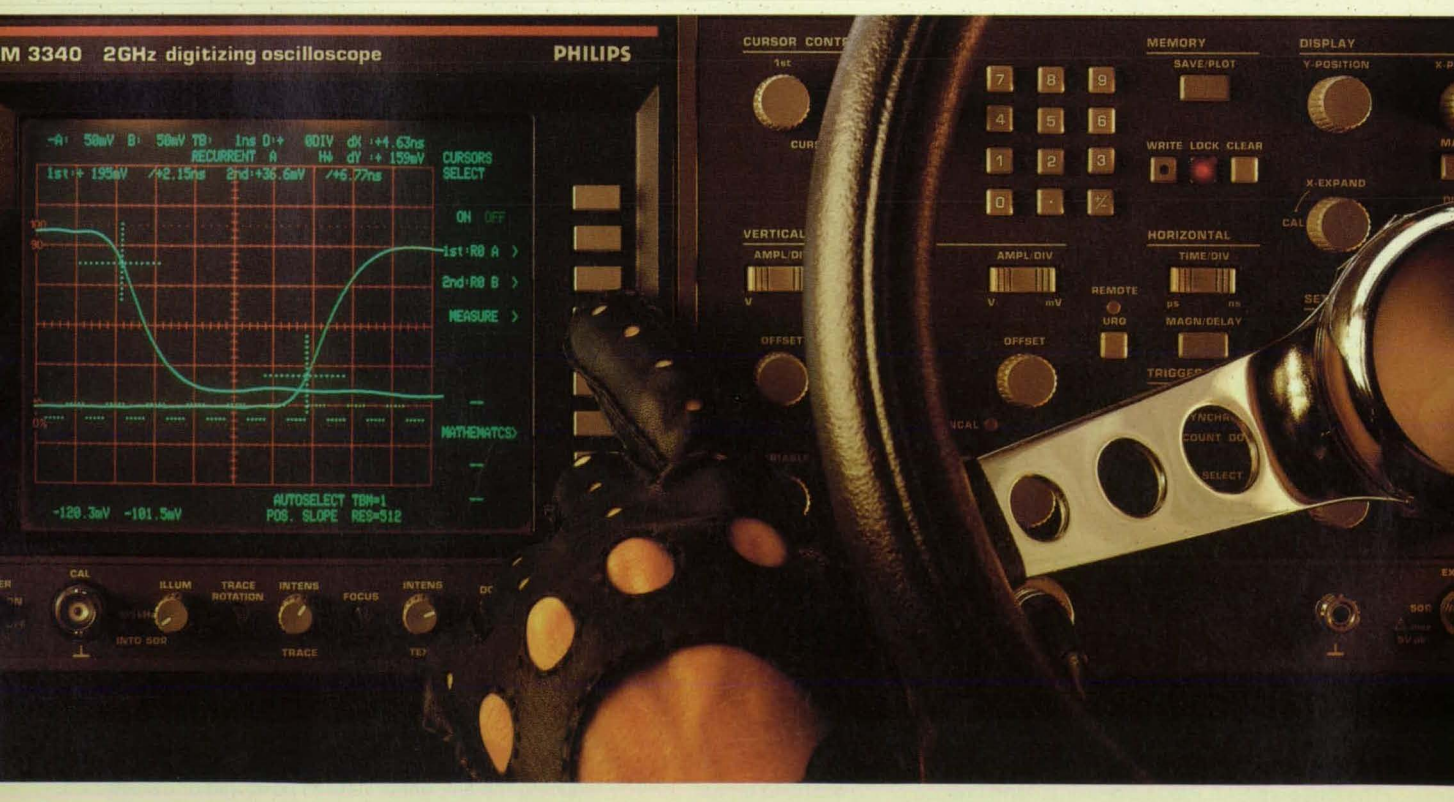
Numerical simulations will be followed by piloted simulations.

A report describes the early stages of development of a control system that will enable a helicopter to follow automatically the contours of the terrain below it and avoid collisions with the terrain. The report focuses on the optimization of the algorithm for the generation of the flightpath with respect to several variables, the development of a controller to position the helicopter precisely along the terrain-following/terrain-avoidance (TF/TA) flightpath, and integration of the flightpath-trajectory software with flightpath-control software.

The trajectory-generating algorithm first generates the horizontal components of the trajectory between specified way points, then generates the vertical components to maintain the required clearances above the ground. The algorithm evaluates prospective flightpaths and ranks them according to a cost function that penalizes altitude and lateral deviation from the reference flightpath. A parameter in the cost function can be varied to obtain more terrain following at the expense of terrain avoidance, or vice versa.

A mathematical model of an 18,000-lb (8,200-kg) helicopter, a digital terrain-data base, trajectory-generation software, and the flightpath controller were combined to produce an off-line computer simulation of the complete terrain-following/terrain-avoidance system. This model will be used

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to optimize the system for an anticipated piloted simulation in the Vertical Motion Simulator at Ames Research Center.

Since the guidance software requires a finite time (about 5 seconds) to compute the trajectory for flight over a new patch of ground that lies ahead, the aircraft states at the start of a patch have to be predicted on the basis of current states and the trajectory for the current patch. Each time the trajectory for a new patch is computed, the solution is passed to the flightpath controller, which then provides control inputs to the helicopter model.

Preliminary results of the numerical simulation show that the trajectory-generating algorithm seeks valleys while maintaining the nominal reference course and that the flightpath controller provides helicopter-control inputs to maintain the desired trajectory. These results indicate that the guidance and flightpath-control software are functioning adequately. Nevertheless, detailed analysis of the integrated system will be required before the piloted simulation can be carried out.

This work was done by Dan W. Dorr of **Ames Research Center**. *Further information may be found in NASA TM-88323 [N87-13122/NSP], "Rotary-Wing Aircraft Terrain-Following/Terrain-Avoidance System Development."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 18]. Refer to ARC-11731.

Design and Analysis of Optical Communication Links

The signal-to-noise ratio alone does not indicate the level of performance.

A report presents a method of design and analysis of an outer-space optical communication link that uses pulse-position modulation (PPM) and in which the received signal is sufficiently weak to require detection by a photomultiplier operating in the photon-counting mode. In such a system a traditional intuitive understanding of radio-frequency communications does not lead to an adequate method of design and analysis. Although the bit signal-to-noise ratio suffices to rank the performance of a radio-frequency system, the performance of an optical system depends on the signal and noise powers in a more complicated way. The report is an attempt to convey to prospective designers an intuitive understanding based on the unique characteristics of optical communication systems.

The dominant limitation on performance is usually not due to noise originating in the receiver (as in the radio-frequency case) but rather is due to the received background noise. Because of this and because of the peculiarities of photon-counting statistics, an evaluation of performance involves the following three basic steps.

Step 1 requires some knowledge or assumptions about the parameters of the transmitter and receiver. The average number of signal photons detected per signal pulse is calculated from the size of the receiver aperture; the energy of each pulse; the divergence of the transmitted light beam; the wavelength; the transmission distance; the quantum efficiency of the detector; and attenuation in the transmitting optics, the receiving optics, and the atmosphere.

Step 2 is the determination of the average number of background-noise photons detected during a PPM timeslot. This number depends on the slot time; the receiver characteristics considered in step 1; the size of the receiver field of view; and the sizes and luminosities (at the designated wavelength) of stars, planets, or other optical-noise sources within the field of view.

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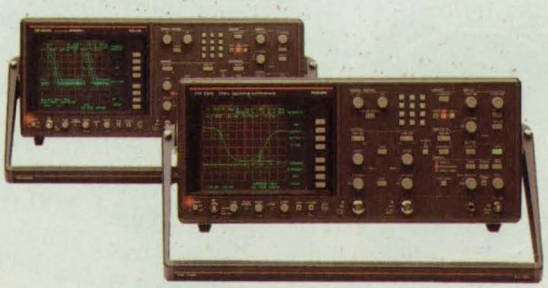
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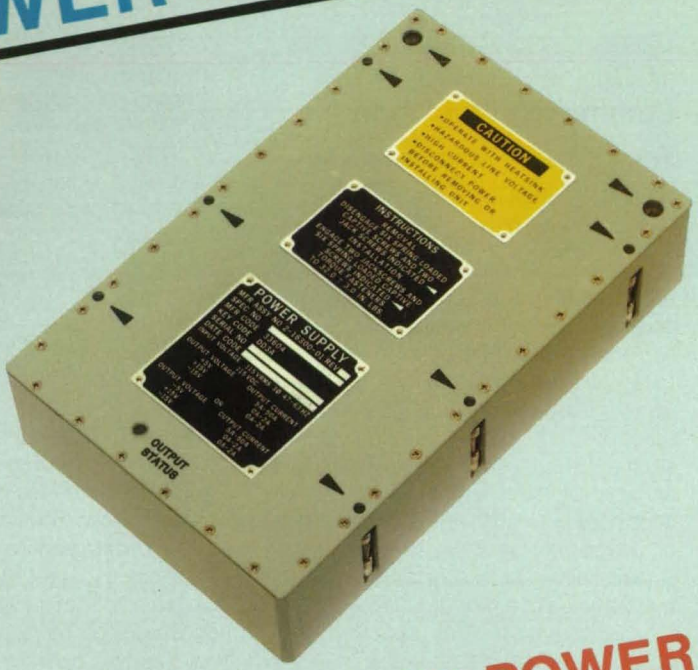


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In step 3 the average number, P_S, of signal photons detected per signal pulse is compared with the average number, P_N, of noise pulses detected per PPM timeslot. To enable an assessment of performance, the comparison is made by reference to a plot of the P_S that would be required to achieve a given bit-error rate at a given P_N: this plot is a function that depends on the particular PPM code. If the data are transmitted in a Reed-Solomon or other error-correcting code, the required P_S is lower.

The three steps would ordinarily be performed in the above order in the analysis of an existing or proposed system. However, the steps can be performed in any order suitable to a specific task: for example, in designing a system that must achieve a specified bit-error rate, noise-photon figure, or signal level, it is best to do step 3 first.

This work was done by J. R. Lesh, W. K. Marshall, and J. Katz of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "A Simple Method for Designing or Analyzing an Optical Communication Link" Circle 106 on the TSP Request Card.*
NPO-17017

Photovoltaic Generation of Power by Utilities

Recent publications are surveyed.

A bibliography of recent documents on photovoltaic generation of electric power is divided into two subject areas: (1) central-station systems and (2) residential and intermediate systems. These classifications are further divided into design options, performance modeling, construction experience, operating experience, economics and costs, and integration with utilities. Reports, papers, and books are included.

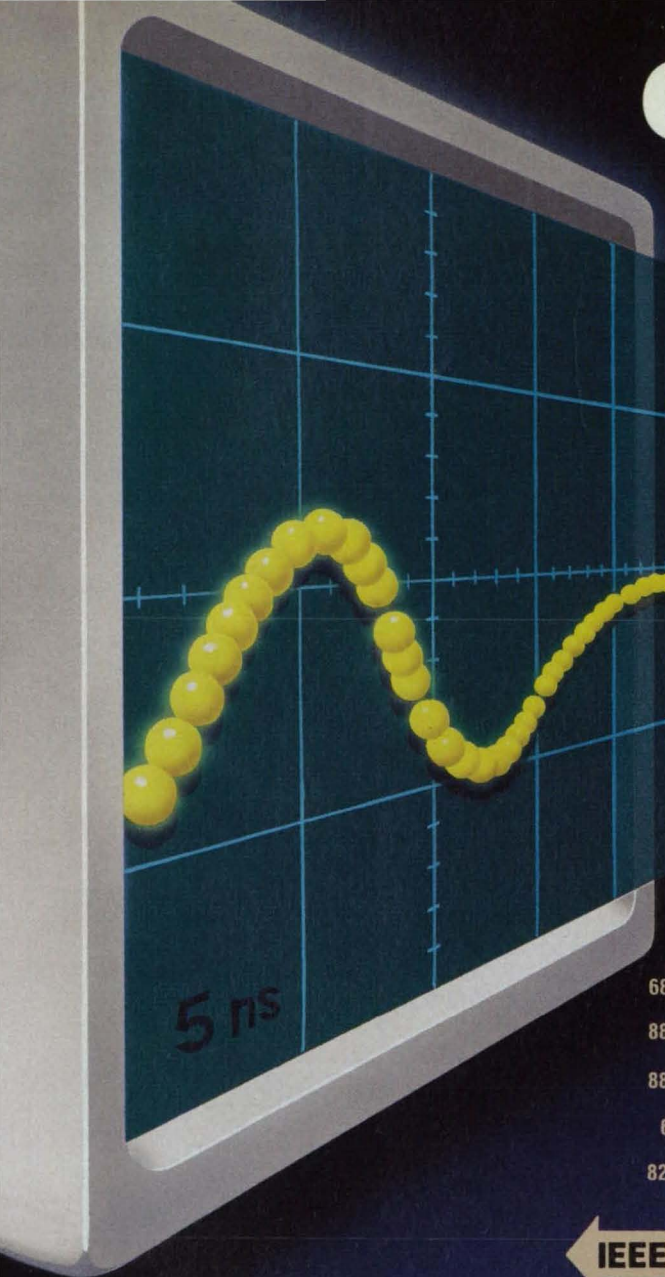
The emphasis is on central stations and large intermediate systems. However, some documents address the utility interface issues in terms of residential systems and their effects on utilities. In addition, references to some stand-alone systems are included because they address design issues and solutions to problems shared with utilities.

The bibliography lists 79 references. For most, it provides a brief description of the contents.

This work was done by Russell S. Sugimura of Caltech and Joan M. Wood of the Tennessee Valley Authority for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the bibliography, "Utility Application of Photovoltaic Power Generation: A Survey of Recent Literature," Circle 60 on the TSP Request Card.*
NPO-17091

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Photovoltaic Hydrogen Sensor

The quantum efficiency of a cell decreases in the presence of hydrogen.

NASA's Jet Propulsion Laboratory, Pasadena, California

A photovoltaic device that senses hydrogen has been developed to test the degradation of diodes that have platinum flash gates (thin platinum coats) on their backs. The sensing element is a p/n junction rather than a conventional Schottky barrier or metal oxide/silicon field-effect transistor. The hydrogen-indicating electrical signal is modulated optically rather than electrically.

The device (see Figure 1) includes a positively doped (p) substrate and a negatively doped (n) front layer. A passivating layer of oxide 20 Å thick is grown on the back, followed by a layer of platinum 10 to 20 Å thick (platinum flash gate). Electrical contacts are made to the p and n regions but not to the platinum. When light is incident on the back surface, most of it passes through the thin Pt and oxide layers and is absorbed in the silicon, where it generates electron/hole pairs. The p/n junction separates the electrons from the holes, and the current collected through the contacts is directly proportional to the absorption of light in the silicon, as in ordinary photovoltaic cells.

Because Pt has a work function that is high in comparison with that of p-type silicon, it creates a region of accumulated positive charge at the back surface. When hydrogen is present at the surface of the platinum, it causes a decrease in the accumulation field at the surface of the silicon, probably by the formation of a dipole layer at the Pt/SiO_2 interface. This change in the accumulation field degrades the quantum efficiency of the device, thereby causing a decrease in photocurrent. The amount of decrease depends on, and can therefore be used to indicate, the relative concentrations of hydrogen and oxygen.

As shown in Figure 2, the sensor gradually approaches a steady, decreased value of quantum efficiency about half an hour after the hydrogen atmosphere is introduced. The removal of the hydrogen atmosphere restores the full quantum efficiency in less than 1 minute. The device is most sensitive at a wavelength (about

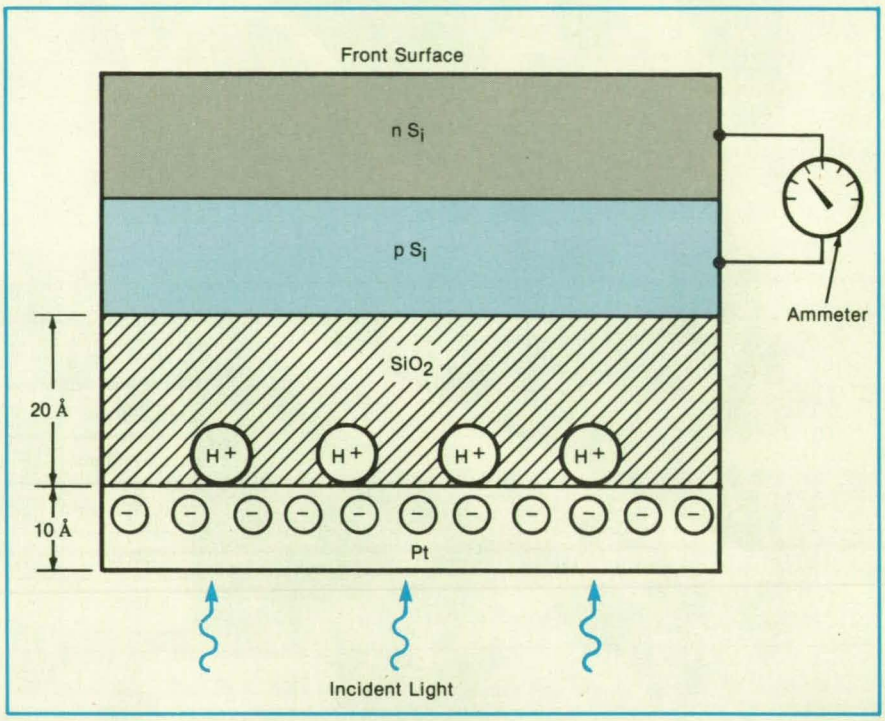


Figure 1. The **Layered Structure of the Hydrogen Detector** and its principle of operation resemble those of a silicon solar photovoltaic cell.

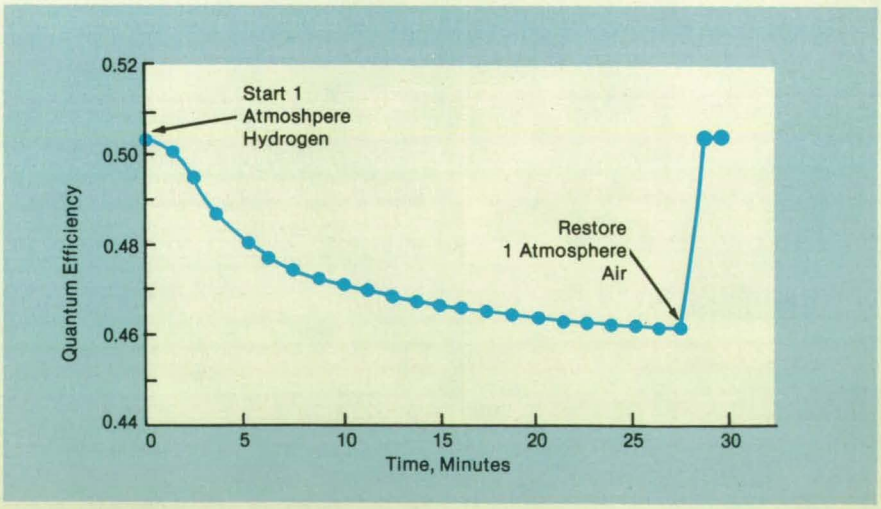


Figure 2. The **Hydrogen Detector Responds** to hydrogen in the atmosphere within minutes and recovers quickly when the hydrogen is removed.

4,000 Å) at which most of the light is absorbed at a depth of a fraction of a micron from the back surface.

This work was done by Taher Daud, James R. Janesick, and John Lambe of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 48 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-17124, volume and number of this NASA Tech Briefs *issue, and the page number.*

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Evolution of Cenospheres

Microscopy reveals changes in structure during combustion.

Experiments have been performed to trace the evolution of the structures of droplets of burning fuel oil. Many droplets burn incompletely, forming cenospheres. Knowledge of the structure at various stages of the combustion process may contribute to efforts to design equipment that will burn the cenospheres.

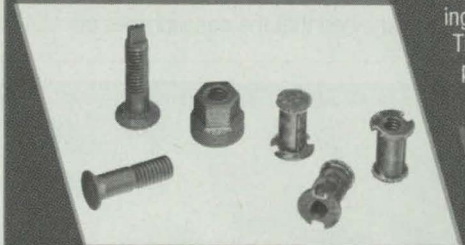
The experimental burner was designed for No. 2 fuel oil but fed with No. 6 fuel oil, which is 500 times as viscous at room temperature. The oil was preheated to 380 °F (193 °C) to reduce its viscosity and sprayed in a cone 80° wide at a pump pressure of 130 psig (0.90 MPa). Residues that emerged from the flame were collected on glass plates.

The residues were coated with thin layers of gold/palladium alloy to enhance the reflection of electrons, then examined by scanning-electron microscopy. Several different types of particles were found, including partially-burned spherical oil drops, cenospheres, and clusters of bubbles. The partially-burned oil drops had very smooth surfaces and ranged in size from 40 to 60 μm. Most of the cenospheres had sizes ranging from 7 to 40 μm; some were larger than 70 μm. The cenospheres had pores of various sizes, indicative of degrees of disruptive motion of fuel vapor inside. Some holes contained pores within pores. Some cenosphere had fewer holes, possibly because they were not burned completely. Some cenospheres were covered with loose, fuzzy soot. The more porous cenospheres appear to be more completely burned. The residues also contained clusters of bubbles ranging in size from 80 to 130 μm.

Because large numbers of droplets are exposed to a variety of environments in and around the combustion zone, the observed structures are believed to represent all stages of the formation of cenospheres and suggest the following sequence of events. In a droplet destined to become a cenosphere, initially the volatile components at the surface and those that diffuse to the surface evaporate to form a diffusion-type flame. The removal of the volatile components leaves behind a viscous shell of asphaltene and resin. The shell slows further diffusion of volatiles; but as the temperature rises inside, additional volatile material vaporizes, causing the drop to expand. Eventually, the volatile material forces its way out, forming a blowhole in a weak spot of the shell. The shell then contracts by surface tension. At the end of vaporization, a hollow shell remains. Also, ejection of gaseous fuel may blow a part of the viscous surface of a drop into a bubble.

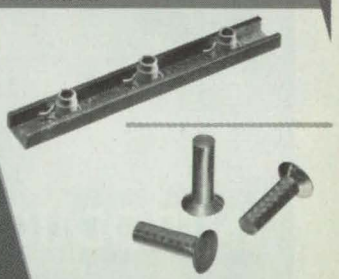
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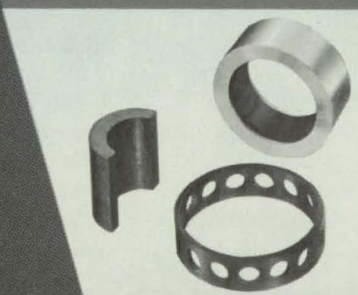


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3/88

Then the bubbles formed from the same or adjacent pores may coalesce, forming large clusters of bubbles.

This work was done by Eug Y. Kwack, Parthasarathy Shakkottai, Paul F. Massier, and Lloyd H. Back of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Particulate Structure in Heavy Fuel Oil Burner Experiments," Circle 58 on the TSP Request Card.*
NPO-17239

Characteristics of Cenospheres

Porosity, other structural features, and composition have been examined.

Physical and chemical studies have been conducted to determine the structure and composition of cenospheres — the small, carbonaceous spheres produced by liquid-phase cracking of the burning droplets of heavy fuel oil. The cenospheres, which burn more slowly than does the original fuel, contribute to deposits, high-temperature corrosion, emissions of particles, and reduced efficiency of combustion in oil-fired furnaces and boilers, accounting for as much as 3 percent of the original fuel in some droplets. These studies should contribute to efforts to burn fuel oil more completely to avoid the deleterious effects of incomplete combustion.

Examinations by optical and scanning-electron microscopy showed that a typical cenosphere is hollow, is spheroidal with an outer diameter of 20 to 200 μm (that is, 1.3 to 1.4 times the inner diameter), and has at least one blowhole that extends from the hollow core through the shell. The diameters of blowholes range from 10 to 50 percent of the diameters of the cenospheres. The shells are porous — the larger ones appearing spongelike, the smaller ones appearing smoother but containing many pores a few micrometers in diameter. The solid portions appear flaky or layered, and the spaces between flakes or layers may contribute to microporosity.

Measurements by mercury-intrusion porosimetry and adsorption of gases showed that the large pores contribute most to the total pore volume while the small pores contribute most to the total surface area. A combination of mercury-intrusion and helium-displacement pycnometry yielded a density of about 2.4 g/cm^3 and showed that only about 18 percent of the volume of a typical cenosphere is occupied by solid material. These observations are consistent with the hollow, porous structure established microscopically.

Standard semiquantitative elemental and spectrographic chemical analyses showed that the cenospheres contain relatively high concentrations of sulfur (3.8 percent), iron (5.5 percent), sodium (0.3 percent), and vanadium (0.1 percent). Previous studies have shown that these elements may contribute to corrosion where cenospheres are deposited on heat exchangers. However, the measurements also showed concentrations of magnesium (3.5 percent) and calcium (0.2 percent), both of which are constituents of additives that are sometimes mixed with fuel oils to inhibit corrosion.

This work was done by Richard M. Clayton and Lloyd H. Back of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Physical and Chemical Characteristics of Cenospheres from the Combustion of Heavy Fuel Oil," Circle 36 on the TSP Request Card.*
NPO-17236

Oxidation of Reflectors Through Pinholes in Coatings

Impacts of particles create paths for corrosion by monatomic oxygen.

A report describes experiments to determine the effects of monatomic oxygen on reflectors that have been damaged by hard particles. The report applies to reflectors for solar dynamic power systems in

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low orbit around the Earth, where neutral monatomic oxygen is the major constituent of the atmosphere. This species is highly corrosive and attacks a variety of materials.

In the experiments, silver mirrors with protective coatings were subjected to streams of 27-μm alumina particles to create pinhole defects. In each case, the protective coating was a layer of silicon dioxide about 2,200 Å thick on a layer of aluminum dioxide 700 Å thick on the silver. Samples were prepared on both graphite/epoxy composite and fused-quartz substrates. After erosion by the alumina particles in a commercial abrasive-blasting machine, the samples were exposed to monatomic oxygen in an air plasma activated by continuous-wave radiation at a frequency of 13.56 MHz. The combined effects of the hard particles and the oxygen plasma were examined by both reflectance measurements and scanning electron microscopy.

It was evident that a coating cannot protect indefinitely against degradation by oxygen plasma when pinhole defects are present. In the samples on the graphite/epoxy substrates, the substrates as well as the mirrors were oxidized through the pinholes. Undercutting, once it began, proceeded at a rapid rate. At undercut sites, the surfaces collapsed, indicating that the underlying support of the mirror was disappearing.

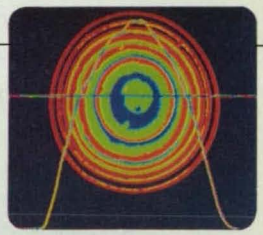
In samples on fused-quartz substrates, the silver oxidized at a slower rate. The silver oxide protruded through the pinholes, indicating that there was insufficient space beneath the protective coatings to accommodate the expanding oxide. This would be expected if the substrate were not oxidizable, as was the case for fused quartz.

A mirror would have to be in low orbit around the Earth for a long time before a significant number of pinholes developed as a result of micrometeoroid or space-debris impacts. It is more likely that pinholes would develop during manufacturing, transportation, and deployment. Whatever their sources, the defects would have to exist in space for an extended period before the loss of reflectance from oxidation would be appreciable. It would be necessary to test a mirror sample in orbit to determine the precise rate of loss of reflectance.

This work was done by Daniel A. Gulino of **Lewis Research Center**. *Further information may be found in NASA TM-88874 [N87-11838/NSP], "Effect of Hard Particle Impacts on the Atomic Oxygen Survivability of Reflector Surfaces With Transparent Protective Overcoats."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14649

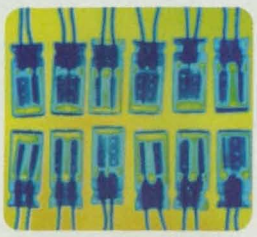
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Materials

Hardware Techniques, and Processes

40 Acetylene-Terminated Aspartimides and Derived Resins

40 Detecting Residues on Grit-Blasted Surfaces

41 Low-Dielectric Polyimides

42 Ultra-High-Molecular-Weight Silphenylene/-Siloxane Elastomers

Acetylene-Terminated Aspartimides and Derived Resins

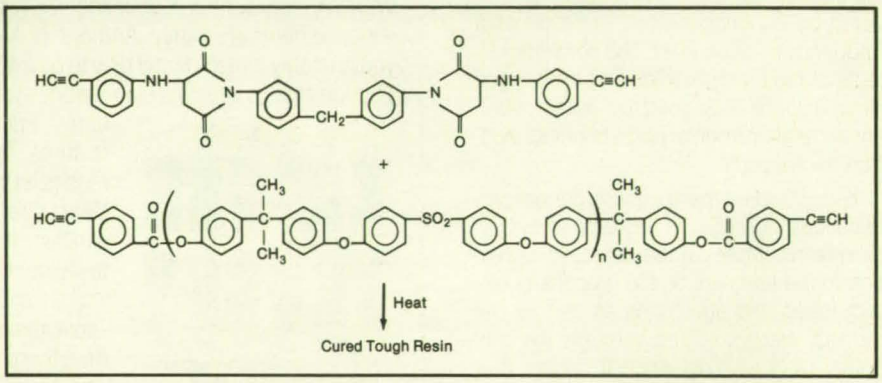
New polymers and derived blends exhibit improved processability and properties.

Langley Research Center, Hampton, Virginia

Structural resins with favorable combinations of such properties as long-term environmental durability over moderate temperature ranges, tolerance to damage, and resistance to solvents are required for use in hot areas on advanced and commercial aircraft. The new toughened epoxies exhibit excellent properties, but the use temperatures are limited. Bismaleimide resins are some of the base materials being formulated to develop materials that have moderate use temperatures. Accordingly, work has been conducted on the use of the acetylenic (ethynyl) group to cross-link and extend the chains of oligomers and polymers to obtain materials that can perform at higher temperatures. This work has been extended to include acetylene-terminated aspartimides (ATA's).

Novel ATA's were prepared from the reaction of 3-aminophenylacetylene with aromatic bismaleimides and also from the reaction of N-(3-ethynylphenyl)maleimide with aromatic diamines. These ATA's exhibited lower melt temperatures (better processability), higher fracture toughness (better resistance to impact), and better adhesive properties than those of comparable bismaleimides. Novel blends of these ATA's with acetylene-terminated polyarylene ethers were prepared and evaluated as moldings, adhesives, and composite matrices. These cured materials exhibited good fracture toughness, resistance to solvents, and adhesive and composite properties.

For example, the ATA from the reaction of 3-aminophenylacetylene and N,N'-bismaleimido-4,4'-diphenylmethane was blended with an equal weight of an acetylene-terminated sulfone oligomer (see figure). The resulting blend was then molded and cured. A fracture-toughness (K_{Ic}, critical stress intensity factor) value of approximately 1,400 psi•in.$^{1/2}$ (1.5 MPa•m$^{1/2}$) was obtained from a specimen molded at a temperature of 230 to 250 °C and a pressure of about 60 psi (0.4 MPa) for 0.5 h. This specimen was not affected by methylene chloride or other solvents. Titanium-to-titanium specimens of the blend provided average tensile shear strengths of 3,600 psi (25 MPa) at 25 °C, 3,200 psi (22 MPa) at 177 °C, 3,000 psi (21 MPa) at 177 °C after 1,000 hours, and 2,600 psi (18 MPa) at 203 °C. The tested specimens exhibited predominantly cohesive failure. The flash from one specimen exhibited a glass-transition temperature of 194 °C.



A **Blend** of an acetylene-terminated aspartimide and an acetylene-terminated sulfone oligomer is heated to produce a cured tough resin.

A prepreg of carbon/graphite fabric was solution-coated with the blend and used to fabricate a final composite with a resin content of approximately 41 percent. The resulting composite at 25 °C exhibited flexural strength, flexural modulus, and short-beam shear strength of 93,500 psi (645 MPa), 7,575,000 psi (52.2 GPa), and 8,600 psi (59 MPa), respectively. At 177 °C, the respective values were 87,800 psi (605 MPa), 6,266,000 psi (43.2 GPa), and 7,200 psi (50 MPa).

This work was done by Paul M. Hergenrother of **Langley Research Center**, *John W. Connell of Virginia Commonwealth University, and Stephen J. Havens of PRC Kentron, Inc. For further information, Circle 110 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 18]. Refer to LAR-13730.

Detecting Residues on Grit-Blasted Surfaces

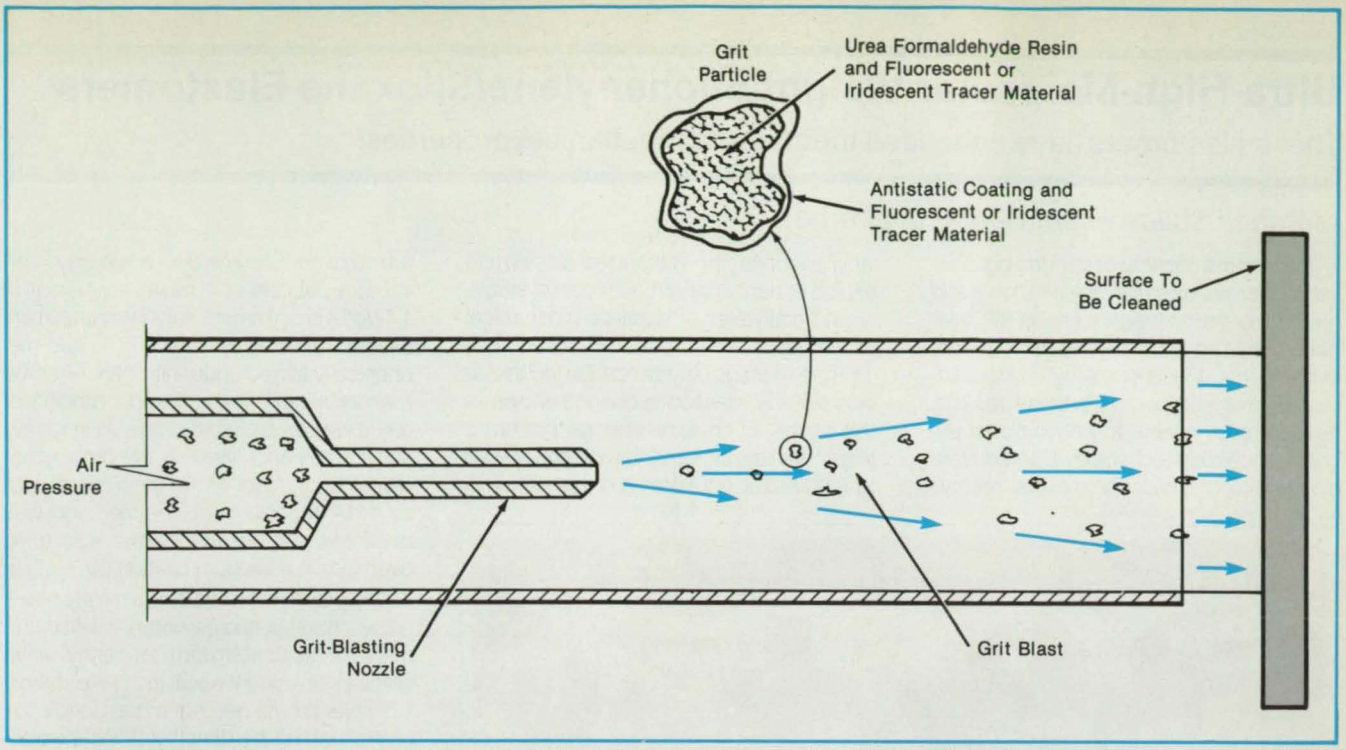
Fluorescent or iridescent additive would reveal unwanted deposits.

Marshall Space Flight Center, Alabama

The addition of a fluorescent or iridescent material to plastic grit particles has been proposed for the detection of grit residues after grit-blast cleaning. Residual films would be visible by observing grit-blasted surfaces under infrared or ultraviolet light.

The embedded residues, which are virtually impossible to detect otherwise, sometimes prevent the proper adhesion of paint or other coatings to grit-blasted surfaces. There is also evidence that the embedded grit and/or surface contamination may increase stress corrosion and reduce fracture strength.

The fluorescent or iridescent material would be added to both the urea formaldehyde grit particles and the monomolecular



Plastic Grit would contain a fluorescent or iridescent additive in its core and its coating. Wherever the grit material became embedded, the additive would make it visible under infrared or ultraviolet light.

layers of antistatic material on the surfaces of the particles (see figure). The fluorescence or iridescence would not only reveal the presence of the residue but would also show, by increasing frequency of deposits, that the antistatic coating has been worn off much of the grit or that the grit is becoming too fine and should be replaced.

The concept may also be applicable to other grit materials. For example, the fluorescent or iridescent material could be added to particles of glass, silicon carbide, aluminum oxide, or zirconium silicate.

This work was done by H. L. Novak and L. M. Zook of United Technologies Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 18].Refer to MFS-28276.

Low-Dielectric Polyimides

Dielectric constants as low as 2.4 are achieved.

Langley Research Center, Hampton, Virginia

Linear aromatic condensation polyimides are being used increasingly by the electronic circuit industry as high-performance film and coating materials. The dielectric constants of commercially available polyimides currently used as passivants and interlevel dielectrics range from approximately 3.2 to 4.0. The lower limit of 3.2 is attained only in fully desiccated films. As a film or coating absorbs moisture, the dielectric constant rises, thereby complicating measurements and the operation of electronic devices.

A new process has been developed to produce aromatic condensation polyimide films and coatings that have dielectric constants in the range of 2.4 to 3.2. These materials are better electrical insulators than are state-of-the-art commercial polyimides. Several of these low-dielectric-constant polyimides have excellent resistance to moisture. They should prove highly useful as film and coating materials for both industrial and aerospace applications where high electrical insulation, resistance to moisture, mechanical strength, and thermal stability are required.

The process for producing these low-dielectric aromatic polyimides involves two conditions: (1) the suppression of chain/chain electronic interactions in the polymer by alteration of the molecular structure and (2) the incorporation of fluorine atoms into the backbone of the polymer. Adherence to the first condition results in a polyimide with a dielectric constant below 3.2. For maximum insulative properties, however, both conditions must be met to produce a moisture-resistant polyimide with a dielectric constant in the range of 2.4 to 2.8.

Chain/chain electronic interactions are suppressed by one or more of the following measures:

1. Reducing the acidity of the dianhydride monomer or basicity of the diamine used to make the polyimide by the addition of separator or linking groups to the molecular structure;
2. Incorporating physical "kinks" in the polymer chains by use of meta-linked diamine monomers; and
3. Incorporating bulky groups that hinder the interactions between chains.

Fluorine atoms are added to the backbone of the polymer by use of $-CF_3$ groups in both the dianhydride and diamine monomers.

This process is applicable to the production of high-temperature and moisture-resistant adhesives, films, photoresists, and coatings. It is of particular value for such electronic applications as printed-circuit boards, both of the composite and flexible-film types. The low-dielectric polyimides produced by this technique have considerable potential for use in the automotive, aerospace, and electronic industries.

This work was done by Anne K. St. Clair, Terry L. St. Clair, William P. Winfree, and Bert R. Emerson, Jr., of **Langley Research Center**. *For further information, Circle 101 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 18]. Refer to LAR-13769.

Ultra-High-Molecular-Weight Silphenylene/Siloxane Elastomers

These elastomers have enhanced thermal and mechanical properties.

Marshall Space Flight Center, Alabama

Elastomers capable of performing in extreme thermal/oxidative environments and having molecular weights above 10^6 have been prepared and analyzed in laboratory experiments. Made of methylvinylsilphenylene-siloxane terpolymers, these new materials are amenable to conventional silicone-processing technology. Compared to similarly formulated commercial methylvinyl silicones, the vulcanized elastomers exhibit enhanced thermal/oxidative stability and equivalent or superior mechanical properties.

The two-stage polymerization technique involved the reaction sequence shown in the figure. Each experimental synthesis began with the incremental addition of 0.90 to 0.98 molar equivalents of bis(dimethylamino)dimethylsilane over a two-day interval to a solution of 1 molar equivalent of 1,4-bis(hydroxydimethylsilyl)benzene in dry toluene refluxing at 95 to 105 °C and mechanically stirred under nitrogen. After the reaction mixture was refluxed an additional day, it was precipitated dropwise in rapidly stirred methanol, yielding the prepolymer (about 80 percent of the theoretical yield) as a low-viscosity gum. The methanol was decanted and the prepolymer was dried overnight in a vacuum oven at 50 °C.

The prepolymer was then similarly reacted over another two-day interval with increments of bis(dimethylamino)-methyl-vinylsilane in an amount equal to approximately 1.6 times the 7.5-percent molar deficiency of the starting bis(dimethylamino)-dimethylsilane. When the reaction was complete, the hot solution was dripped as before into rapidly stirred methanol, the methanol was decanted, and the product, a rubbery gum, was dried in a vacuum oven at 50 °C for two days. A typical yield of polymer is 95 percent, based on the amount of prepolymer used.

Finally, rubber samples were formulated of 25.0 g polymer, 1.25 g Santocel (or equivalent) fumed silica filler, 2.50 g Super Floss (or equivalent) fumed silica filler and either 0.20 g of 2,5-dimethyl-2,5-di(t-butylperoxy)hexane or 0.44 g dicumyl peroxide. The ingredients were milled for 15 minutes on a microrubber mill, left overnight, vulcanized under pressure for 20 minutes in a preheated mold at 338 °F (170 °C), then removed from the mold and cured for 16 hours in an oven at 450 °F (232 °C).

In measurements of the ultimate strength, Young's modulus, percent elongation at failure, and tear strength, the experimental elastomers proved superior to the commercial methylvinyl silicones. The prepolymers of lowest molecular weight yielded the strongest elastomers. Stronger elastomers were produced with dicumyl peroxide than with 2,5-dimethyl-2,5-di(t-butylperoxy)hexane.

Gradient and isothermal thermogravimetric analyses performed in both air and nitrogen demonstrated superior thermal/oxidation stability for the experimental elastomers. However, despite its inherent thermal stability, the experimental elastomer (like the commercial elastomer) exhibited extensive degradation of its mechanical properties after being exposed to 550 °F (288 °C) for 16 hours.

This work was done by N. H. Hundley and W. J. Patterson of **Marshall Space Flight Center.** *Further information may be*

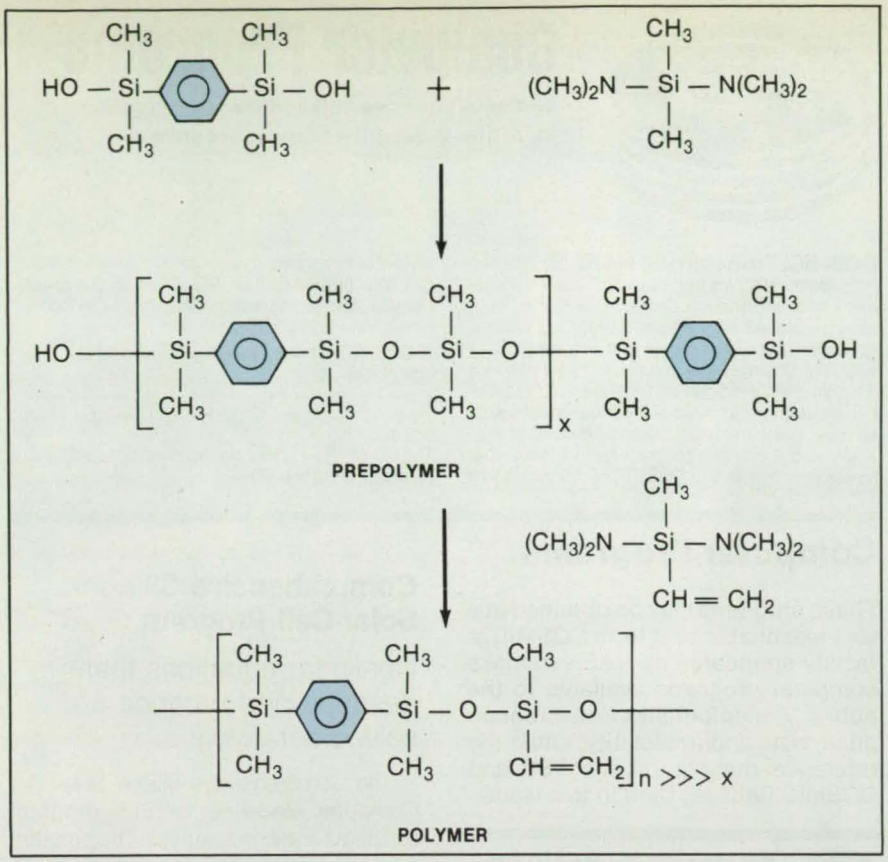
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Methylvinylsilphenylene-Siloxane Terpolymers of molecular weights greater than 10^6 have been prepared by reacting 1,4-bis(hydroxydimethylsilyl)benzene with bis(dimethylamino)dimethylsilane to produce a silanol-terminated prepolymer that is then reacted with bis)dimethylamino)methylvinylsilane.

found in NASA Technical Paper 2476 [N85-26990/NSP], "Formulation/Cure Technology for Ultra-High-Molecular-Weight Silphenylene-Siloxane Polymers" [$7]. A paper copy may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. The report is also available on microfiche at no charge. To obtain a microfiche copy, Circle 54 on the TSP Request Card. MFS-27120



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44 Comprehensive Silicon-Solar-Cell Program
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Electronic Components and Circuits

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The Comprehensive Silicon Solar Cell Computer Modeling (SICELL) program simulates a silicon solar cell. The program predicts such device parameters as efficiency, voltage-vs.-current characteristic, fill factor, and temperature coefficients of parameters. The technique used in SICELL is similar to numerical-integration methods, but the commonality is described only by the use of a mesh-point field. Validation studies show that the accuracies of simulations range from 0.08 percent to 3.6 percent for 27 experimental data points over the temperature range of 300 K to 421 K. These results are obtained by the use of 10 mesh points in the n- and p-type regions and for two iterations.

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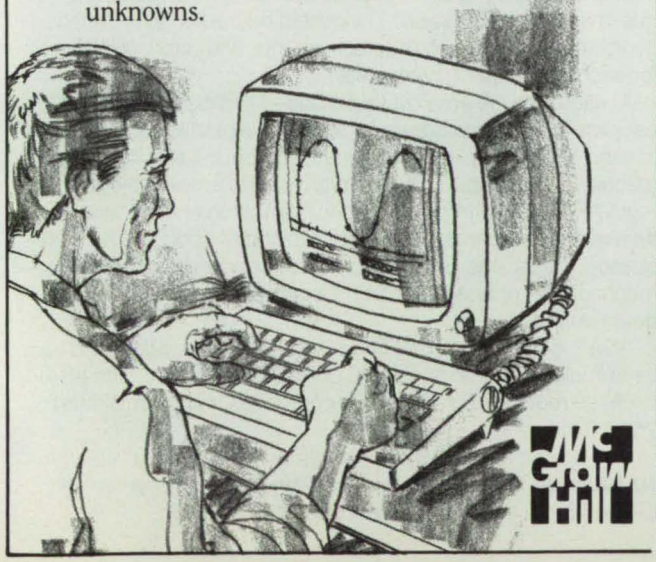
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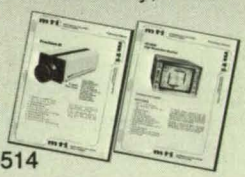
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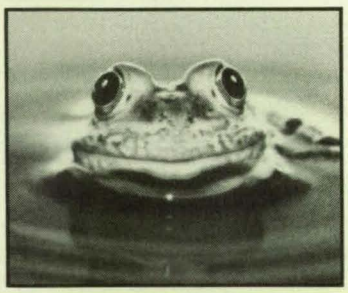
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ters, front- and back-surface recombination velocities and reflectivities, nondegenerate or degenerate absorption coefficients, and mesh-point field distribution in the n- and p-type regions.

SICELL runs interactively on a VAX computer under VMS and is written in VAX/VMS FORTRAN 77. Central memory of approximately 110K of 8-bit bytes is required. The program was developed in 1986.

This program was written by Michael F. Lamorte and William M. Yeager of Research Triangle Institute for **NASA's Jet Propulsion Laboratory.** *For further information, Circle 9 on the TSP Request Card. NPO-17126*

Mechanics

Artificial-Satellite-Analysis Program

Almost any planetary orbiting mission can be simulated.

The Artificial Satellite Analysis Program (ASAP) is a general orbit-predicting computer program that incorporates sufficient orbit-modeling accuracy for the design and planning of missions and the analysis of maneuvers. ASAP is suitable for the study of planetary-orbit missions with spacecraft trajectories of a reconnaissance (flyby) and exploratory (mapping) nature. Sample data are included for the study of the drift cycle of a geosynchronous station, a strategy to map Venus by radar, a frozen orbit about Mars, and a repeat-ground-trace orbit.

ASAP uses Cowell's method in the numerical integration of the equations of motion. The calculation of orbital mechanics contains gravitational perturbations due to nonsphericity (up to a 40 by 40 field) of the planet, lunar and solar gravitational effects, drag, and the pressure of solar radiation. An 8th-order Runge-Kutta integration scheme with variable step size is used for efficient propagation. The input includes the classical osculating elements, orbital elements of the Sun relative to the planet, reference time and dates, coefficient of drag, gravitational constants, and the radius and the rate of rotation of the planet. The printed output contains Cartesian coordinates, velocity, equinoctial elements, and classical elements for each time step or event step.

At each step, selected output is added to a plot file. The ASAP package includes a program for sorting this plot file. LOTUS 1-2-3 is used in the supplied examples to graph the results, but any graphics software package could be used to process the plot file.

ASAP is not written for any specific mission and is intended to be used for almost any planetary orbiting mission. As a consequence, the user has to have some basic understanding of orbital mechanics to provide the correct inputs and interpret the subsequent output.

ASAP is written in FORTRAN 77 for batch execution and has been implemented on an IBM PC operating under DOS. The ASAP package requires the 8087 math coprocessor and a minimum of 256K RAM.

This program was written by Johnny H. Kwok of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, Circle 123 on the TSP Request Card. NPO-17522*

Mechanics

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Computer Programs
46 Artificial-Satellite-Analysis Program

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Numerical Solution of Navier-Stokes Equations

Three-dimensional, incompressible flow is simulated on a computer.

A report discusses the mathematical basis of the IN3SD computer code and the application of the code to several test problems. The code relies heavily on the use of pseudocompressibility to solve numerically the three-dimensional Navier-Stokes equations of viscous, incompressible flow. With further study and some modification, IN3SD promises to become a valuable computational tool for the solution of many engineering problems in fluid dynamics.

The formulation begins with the standard Navier-Stokes equations for the conservation of momentum in viscous, incompressible flow. The pseudocompressibility is introduced by replacing the incompressible-flow continuity equation $\nabla \cdot \mathbf{v} = 0$ with the equation

$$\frac{\partial p}{\partial t} + \beta \nabla \cdot \mathbf{v} = 0$$

where p = pressure, t = time, $\mathbf{v}$ = velocity, and β = the pseudocompressibility parameter. The combined equations are placed in matrix/tensor form suitable for solution in general curvilinear coordinates adaptable to the configuration of the flow or boundary surfaces of the problem at hand.

The equations are advanced in time by the implicit, noniterative, approximately-factored, finite-difference scheme of Beam and Warming. The numerical stability of the scheme depends on the use of higher-order smoothing terms to damp out higher-frequency oscillations caused by second-order central differencing. The artificial compressibility introduces pressure (sound) waves of finite speed (whereas the speed of sound would be infinite in an incompressible fluid). As the solution converges, these pressure waves die out, causing the derivative of pressure with respect to time to approach zero. Thus, continuity is satisfied for the incompressible fluid in the steady state.

Because continuity is not satisfied until the steady state is attained, the solution does not give an accurate history of a flow that varies with time. However, the temporary relaxation of the requirement of continuity enables a significant reduction in the time required for the numerical simulation of the steady-state flow. Furthermore, the method of pseudocompressibility can be used to obtain at least a qualitative indication of the nature of an unsteady flow.

The report presents an analysis of the effect, on the calculations, of the use of different values of β. On the basis of this analysis, it presents guidelines for the proper choice of β for fast convergence of the solution.

The code was tested on a steady, two-dimensional laminar flow over a backward-facing step; a steady symmetric, an impulsively started symmetric, and a vortex-shedding, nonsymmetric, perturbed, two-dimensional laminar flow around a cylinder; and a steady, three-dimensional laminar flow about a cylinder between two end plates. The numerical solution for the backward-facing step and the transient solution for the two-dimensional flow around the cylinder agreed well with experimental observations. The computed frequency of vortex shedding did not agree with the experimental value; this may be due in part to the fact that the calculations did not approach the steady state and the pseudopressure waves never died out. The three-dimensional solution showed a flow field with a saddle-point separation and a horseshoe-shaped vortex system, with secondary vortex filaments wrapping around the cylinder and spiraling up in the wake.

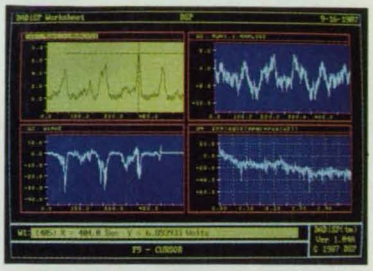
This work was done by Stuart E. Rogers, Dochan Kwak, and James L. C. Chang of **Ames Research Center**. *Further information may be found in NASA TM-86840 [N87-11964/NSP], "Numerical Solution of the Incompressible Navier-Stokes Equations in Three-Dimensional Generalized Curvilinear Coordinates."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

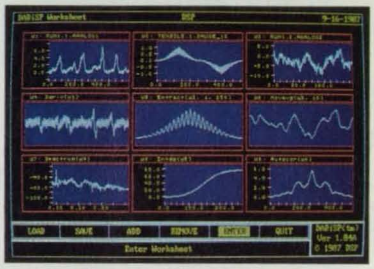
Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center *[see page 18].* *Refer to ARC-11794.*

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Shock-Induced Heating in a Rocket Engine

Misalignments can give rise to hotspots on walls.

A report discusses a numerical simulation of the flow in and near a small, ringlike cavity in the wall of the Space Shuttle main engine at the junction of the main combustion chamber and the nozzle. The purpose of the simulation was to study the effects of misalignments between the combustion chamber and nozzle on the transfer of heat into the surfaces of the chamber, cavity, and nozzle. Depending on the specific misalignment, the flow could encounter a forward- or backward-facing step as it leaves the chamber and enters the nozzle. This could result in serious losses of performance and excessive heating of the walls.

The flow past the cavity includes complicated features like separation and reattachment of the boundary layer and interaction of the boundary layer with a shock downstream of the cavity. Consequently, analytical methods are inadequate to quantify the flow and temperature fields, and numerical simulation is essential. The mathematical model includes only local effects in a meridional-plane slice of the junction cavity and vicinity, and the flow is treated as two-dimensional in this plane. This computational domain is divided into two zones: the deepest portion of the cavity and everywhere else.

The steady, two-dimensional mean-turbulent-velocity and temperature fields are computed via a finite-volume code that solves the Navier-Stokes equations. The code uses total-variation-diminishing spatial discretization to capture shocks without producing unphysical oscillations in the solution. This feature is necessary for the accurate assessment of shock-induced heating downstream of the cavity. The Baldwin-Lomax model of turbulence is used to calculate the turbulent eddy viscosity. The previously-established boundary-layer profile on the wall of the combustion chamber at 109 percent power level is used as the inlet boundary condition, and a temperature of 913.5°R (507.5 K) is assumed for all solid surfaces.

The simulated flow separates from the wall at the upstream edge of the cavity and reattaches at the wall of the nozzle at a point downstream. A shock forms where the flow impinges on the wall downstream and interacts with the boundary layer near the point of reattachment. Upstream of the point of separation and downstream of the point of reattachment, there are fully-developed turbulent boundary layers.

In these upstream and downstream regions, the velocity profile is used to compute a wall shear stress, and then a Reynolds analogy is invoked to relate the wall shear stress to the flux density of heat. Because there is no boundary layer in the cavity, the flux of heat into the walls must be found by a different approach; namely, the calculation of the gradient of temperature in the wall by a second-order-accurate finite-difference approximation.

The results of the numerical simulation are given in contours of pressure, a map of velocity vectors, false-color maps of temperature and pressure, a plot of the flux density of heat as a function of position along the wall of the combustion chamber and the upstream wall of the cavity, and a similar plot of the flux density of heat along the downstream wall of the cavity and the wall of the nozzle. Among other things, the heat-flux plots show a severe rise at the shock. This prediction is confirmed by discoloration (due to overheating) of the wall downstream of the cavity of a test-fired engine.

This work was done by Ronald R. Lagnado and Farhad Raiszadeh of Rockwell International Corp. for **Marshall Space Flight Center**. *To obtain a copy of the report, "Analysis of Shock Induced Heating at the SSME Main Combustion Chamber/Nozzle Junction," Circle 151 on the TSP Request Card.*
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Generation Method Improves Spiral Bevel Gears

Conjugate tooth surfaces reduce kinematic errors.

Lewis Research Center, Cleveland, Ohio

A method for the generation of spiral bevel gears provides conjugated gear-tooth surfaces and improved bearing contact. Conjugated surfaces are preferable because they maintain constant gear ratios during tooth-contact cycles. The changing gear ratios of nonconjugated surfaces give rise to kinematical errors in the transfer of motion from driving gears to driven gears; these errors are major sources of noise in power transmissions (see Figure 1).

The geometry and the generation of spiral bevel gears have been subjects of intensive research. The new generation method is the product of a research effort to eliminate kinematical errors and improve the conditions of lubrication and bearing contact. The new generation method can be practiced by using specially calculated settings on existing Gleason gear-generating machines and tools — an important advantage because such equipment can cut high-quality gears by milling or grinding. The resulting gears have localized bearing contacts, which are typical for Gleason gears and are necessary to reduce the sensitivities of gear-tooth-surface contacts to misalignments and deflections of gear shafts in operation.

The generation concept includes the requirement that the line perpendicular to the meshing gear teeth at the point of contact points in the same direction throughout the process of meshing. This is geometrically equivalent to the constant orientation of a link between two mating ellipses of different orientations and dimensions (see Figure 2). The new generation process causes the contact ellipse to move lengthwise along a gear tooth in the way that is most advantageous for lubrication.

A computer program has been developed to simulate the cutting and meshing processes for pinions and gears, to obtain numerical results to verify that the new generation concept minimizes kinematical errors. The program is based on the principle that, at the instantaneous point of contact between meshing teeth, the position vectors must agree, the equations for meshing between the generating and generated gears must be obeyed, and the lines perpendicular to the surfaces of the teeth must coincide. The outputs are the shapes of the gear teeth, the contact path, the kinematic error, and the contact ellipse between the mating gear teeth.

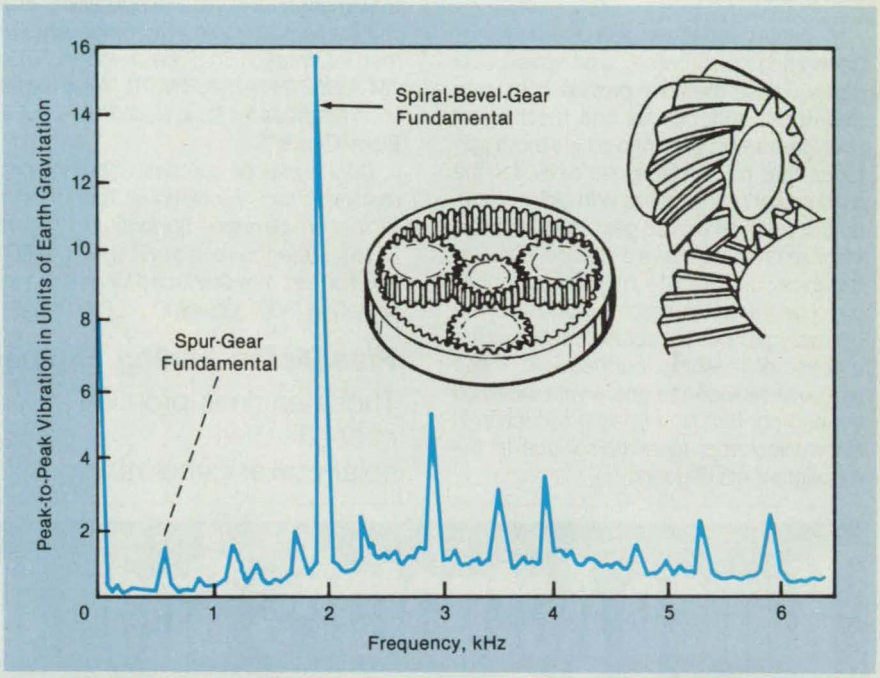


Figure 1. The **Vibration Spectrum** obtained by an accelerometer on the housing of a helicopter transmission shows that the spiral bevel gear caused the most noise and vibration.

The computer analysis was applied to a case in which practical considerations dictated the use of standard blade angles. With the new machine settings, the kinematical errors were very small (less than 0.02 arc seconds), whereas conventional settings yielded kinematic errors ranging from 20 to 90 arc seconds.

This work was done by Faydor L. Litvin and Wei-Jiung Tsung of the University of Illinois at Chicago, John J. Coy of the U.S. Army Aviation Research and Technology Activity — AVSCOM, and Charles Heine of Dana Corp. for **Lewis Research Center**. *Further information may be found in NASA TM-87273 [N86-25793/NSP], "Generation of Spiral Bevel Gears With Zero Kinematical Errors and Computer Aided Tooth Contact Analysis."*

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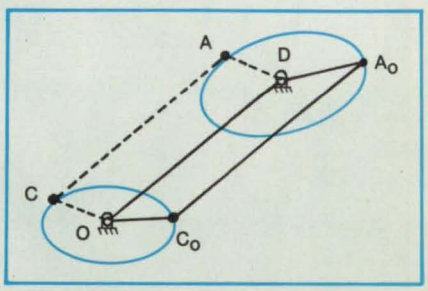


Figure 2. The **Basis for the Machine-Tool Settings** for the generation of conjugate spiral-bevel-gear tooth surfaces is the relation between mating ellipses. The ellipses are traced out by points C and A when the machine cradles rotate about their axes (which pass through points O and D). As it moves along the ellipses, link CA remains parallel to a fixed line $C_o A_o$.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

New Methods for Generating Gear Surfaces

Conjugate surfaces can be generated and analyzed for a variety of useful configurations.

A report presents new methods for generating spur, helical, and spiral-bevel gears. These methods provide conjugate gear-tooth surfaces for the meshing of spur gears with crowned pinion-tooth surfaces that have misaligned axes, for the meshing of helical gears with pinion circular-arc teeth as well as gear regular screw involute teeth that have a change in center distance, and for the meshing of spiral-bevel gears, the common surface of which normally performs a parallel motion in the process of meshing. Furthermore, these methods provide the gears with localized bearing contact as well as a reduction in kinematic errors (gear noise) due to the misalignments of gears.

Computer programs for the analysis of tooth contacts have been developed for these gears. These programs make it possible to simulate gear meshing and bearing contact and to investigate the influence of misalignments of gears on kinematic errors. The proposed gear-generation methods can be applied to the spiral-bevel gears by the use of currently available machinery and tools, but new tool shapes will be required for the spur and helical gears.

This work was done by John J. Coy and Robert F. Handschuh of **Lewis Research Center**, *F. L. Litvin and W.-J. Tsung of the University of Illinois at Chicago, and C.-B. P. Tsay of National Chiao Tun University. Further information may be found in NASA TM-88862 [N87-15466/NSP], "New Generation Methods for Spur, Helical, and Spiral-Bevel Gears."*

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Free-Piston Stirling Engines

These engines promise cost-effective solar-power generation.

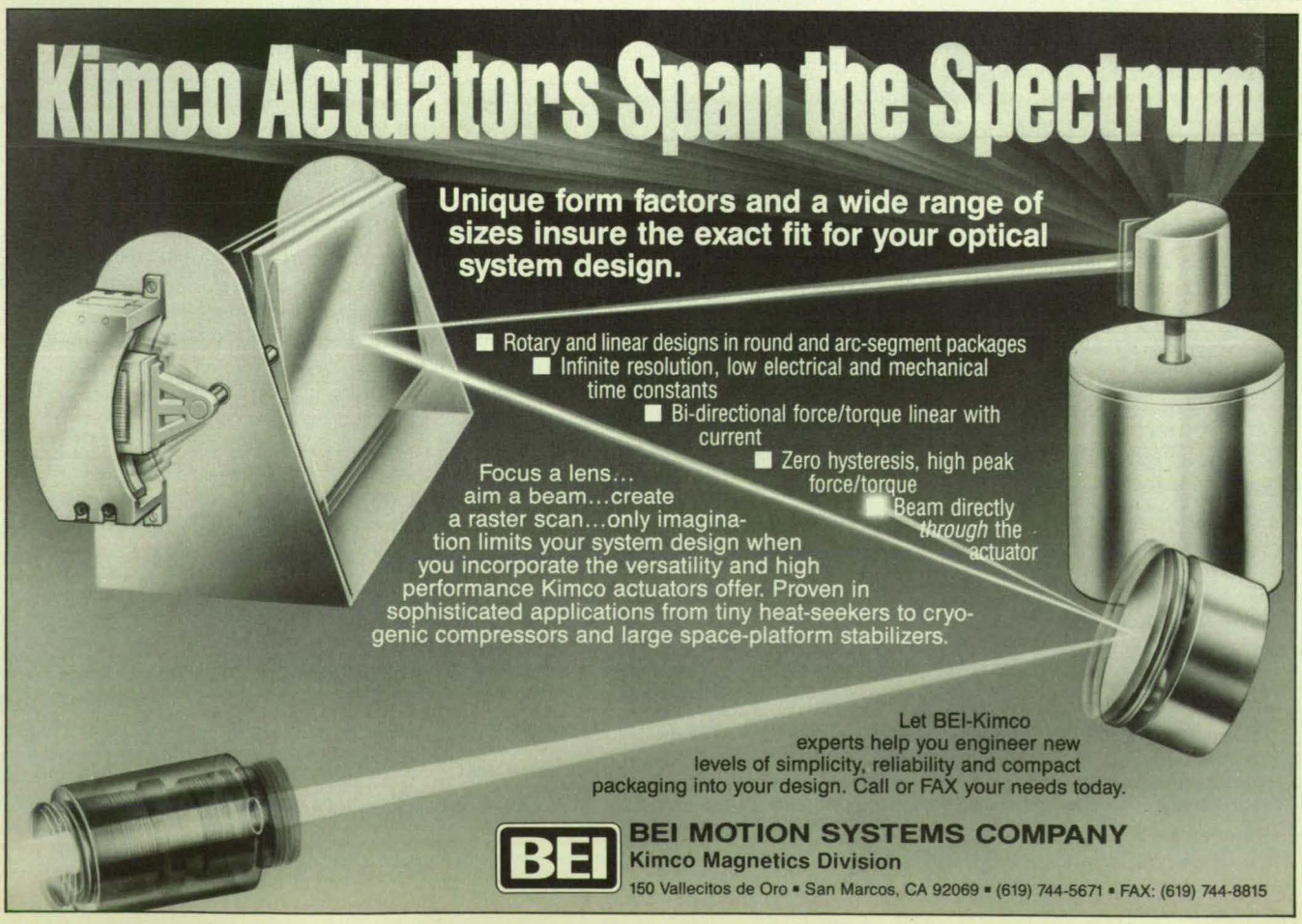
A report describes two concepts for Stirling-engine systems for the conversion of solar heat to electrical energy. Long considered a highly efficient candidate for the dynamic conversion of energy in spacecraft, whether solar-powered or nuclear-powered, the free-piston Stirling engine is now recognized as one of the most promising technologies for meeting the U.S. Department of Energy goals for performance and cost for terrestrial electrical-energy sources.

The report discusses free-piston Stirling engines. Invented in 1962 by William Beale, this type of engine differs from the kinematic Stirling engine invented by Robert Stirling in 1816 in that it has only two moving parts, has noncontacting gas bearings, and can be hermetically sealed. It offers the potential for high reliability and long life.

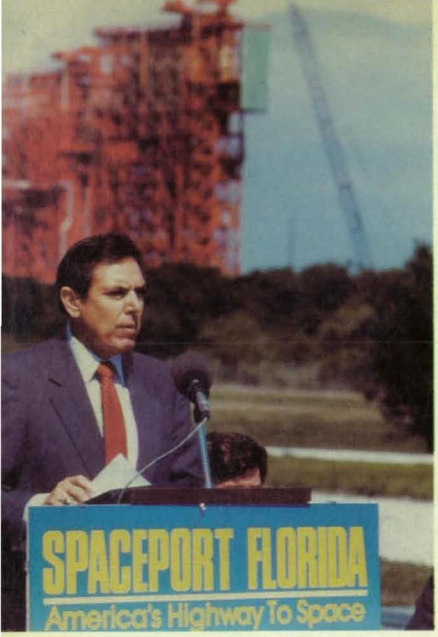
The goal for one of the conceptual systems is to generate about 25 kW of electrical power from Sunlight and feed it to a utility grid at a cost of $300/kW for the engine and alternator system. The system would have a productive lifetime of 30 years.

Both conceptual designs specify a liquid-metal heat-pipe receiver in addition to a free-piston Stirling engine. One concept incorporates a linear alternator to convert the energy to electricity directly. The other concept generates electrical power in-

(Continued on page 77)




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Florida Governor Bob Martinez addresses reporters in front of launch gantry at Cape Canaveral Air Force Station.

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This special issue of NASA Tech Briefs *marks the beginning of the magazine's "Focus on America" series. We are proud that Florida has been chosen as the premier state for the program. As you will see, Florida's enduring commitment to high tech research and economic development is of national and international significance.*

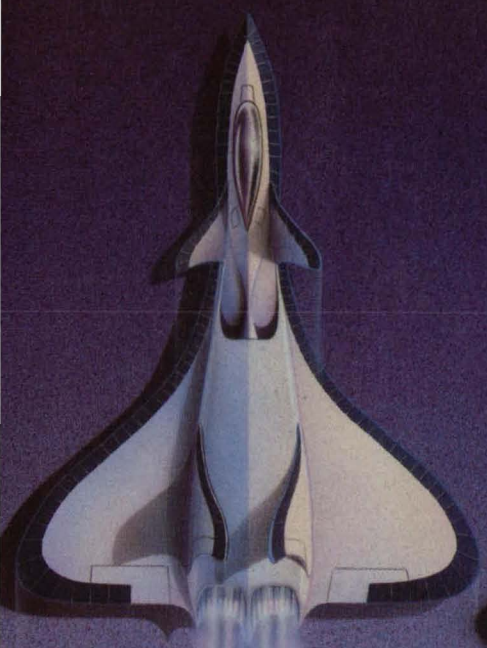
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Florida Lieutenant Governor/Secretary of Commerce Bobby Brantley (left) with Dr. Chris Shove, Director of Space Programs, in front of Launch Complex 17A—one of two commercial launch sites at Cape Canaveral Air Force Station.

Space exploration, research, and utilization have been an important part of Florida's economy since the nation's space program began. Early rocket tests during the 1940s, and the historic 1950 launch of "Bumper 8" from a tiny launch pad on Cape Canaveral propelled Florida into the Space Age. Today, after decades of pioneering research by NASA and the Department of Defense, Florida's efforts to foster the continued development of private-sector space involvement are gaining momentum.

SPACE COMMERCE

Florida's goal is to become the world's center for space-related commerce. Toward that goal, the state has been making strong advances in supporting all facets of space industry. Florida's strategy is attracting worldwide attention and is setting the pace for commercial space development in the United States.

There is an increasing number of commercial applications for space, including satellite telecommunications, microgravity materials research, satellite-aided navigation, and remote sensing. Together these applications represent billions of dollars in commercial investment, and they are expected to grow dramatically over the next decade. However, routine access to space is essential to the continued growth of the commercial space industry.

Following the Challenger tragedy and the nation's subsequent two-and-a-half-year hiatus from space, shuttle payload capacity became strictly reserved for government use. These new restrictions, coupled with the earlier decision to phase unmanned rockets out of the nation's space transportation fleet, left commercial firms with few alternatives for placing their payloads into orbit.

HIGHWAY TO SPACE

Providing commercial access to space is a critical element in Florida's plans to develop space commerce. The state is currently working toward development of a commercial launch facility that will function independently of NASA and Department of Defense space programs. *Spaceport Florida* will be the nation's first commercial spaceport, designed specifically to accommodate present and new generations of private-sector space launch vehicles.

A development plan for the spaceport—to be completed in February, 1989—will define the operational parameters, and indicate potential locations for the facility. The optimal site, according to the study group, would be near the federal government's facilities on Cape Canaveral because of the area's well-developed tracking, processing and support infrastructure, but several other locations around the state also are under study.

A typical launch from Spaceport Florida will include a small communications satellite, a microgravity test capsule, and a commercially owned and manufactured expendable rocket.

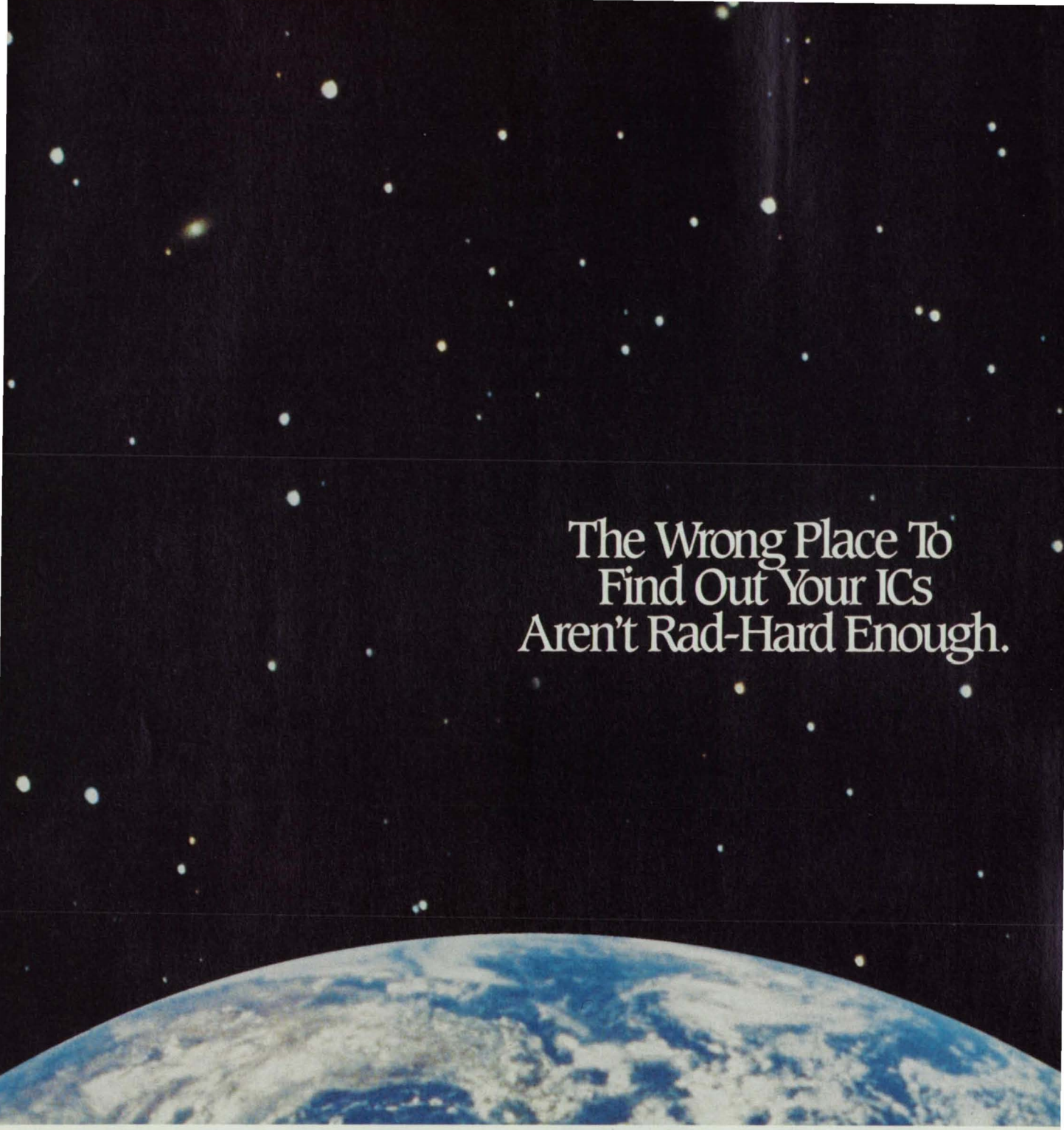
Florida officials are confident that space-related industry growth will accompany the development of Spaceport Florida. Routine, assured access to space will be a major attraction for established aerospace businesses and entrepreneurial companies planning to participate in the commercial use of space.

ONE STEP AT A TIME

Providing the "highway to space" will represent only the first step toward attracting and developing space commerce. Successful space-related firms require talented engineers and access to sophisticated university research facilities. In response to those requirements, a number of educational programs are planned to meet the employment, research and development, and support needs of broad-based space commerce.

This fish-eye view shows a Delta rocket as it's readied for liftoff from Launch Pad 17A on Cape Canaveral Air Force Station.





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Among Florida's recent space-related educational accomplishments and plans:

- $300,000 was allocated to fund a special space-related scholarship program for gifted students;
- $100,000 was allocated for development and acquisition of space-related teaching materials;
- a Space Research Foundation with several million dollars in annual funding was created to support space-related research and education in Florida;
- a million dollar per year Challenger Memorial Scholarship Fund was endowed;
- Florida university efforts to headquarter a NASA Center for the Commercial Development of Space (CCDS) in the state;
- a statewide effort is underway to create space centers of excellence at Florida's universities;
- a resolution was signed by Governor Martinez to bring the International Space University to Florida in 1991;
- A statewide university Space Research Conference will be held in February to promote collaboration among university and industry researchers.

***"Florida's educational system will play a vital role in the development of space commerce in the state. Our schools will provide the engineers, scientists, lawyers, and executives needed for an industry that will grow and mature well into the next century,"*—Governor Bob Martinez**

To implement measures that support space-related commerce in the state, Florida recently created an Office of Space Programs within its Department of Commerce. Though primarily concerned with Spaceport Florida and other aspects of space industry development, the Space Programs Office works to enhance the critical relationship between space-related industry and education.

"Space commerce will grow to multibillion dollar proportions over the next decade as routine access to space becomes a reality," says Dr. Chris Shove, Director of the Office of Space Programs. "A long-term commitment to space industry development must include educational programs, from grade schools to universities, designed to support the industry's future needs."

Educational enhancement programs currently underway in Florida are aimed at increasing space-related university/industry research partnerships; improving vocational training related to space-related industry; including space-related educational programs in grade and middle school curricula and science fairs; increasing intra-university awareness of available federal research funding; and forming space-related scholarship programs.

A number of Florida universities are preparing students for work in the new frontier of commercial space. Besides offering basic and upper-level space curricula, several state universities conduct space-related research at various levels. Those most involved in space research and teaching include the University of Florida, the University of Central Florida, Florida State University, the University of South Florida, Embry-Riddle Aeronautical University, and the Florida Institute of Technology.

These universities receive millions of dollars in sponsored space-related research funds from industry and government agencies such as NASA, the Department of Defense, the National Oceanic and Atmospheric Administration (NOAA), the Department of Energy, and the National Science Foundation. The experience and knowledge that students gain from this research primes them for employment in the rapidly developing laboratory of space.

Florida ranked second last year in total distribution of NASA prime contract awards. The amount, over $397 million, included awards to educational institutions, businesses, and nonprofit organizations.

The successful launch of* Discovery *on September 29, 1988 marked the resumption of America's manned space program.



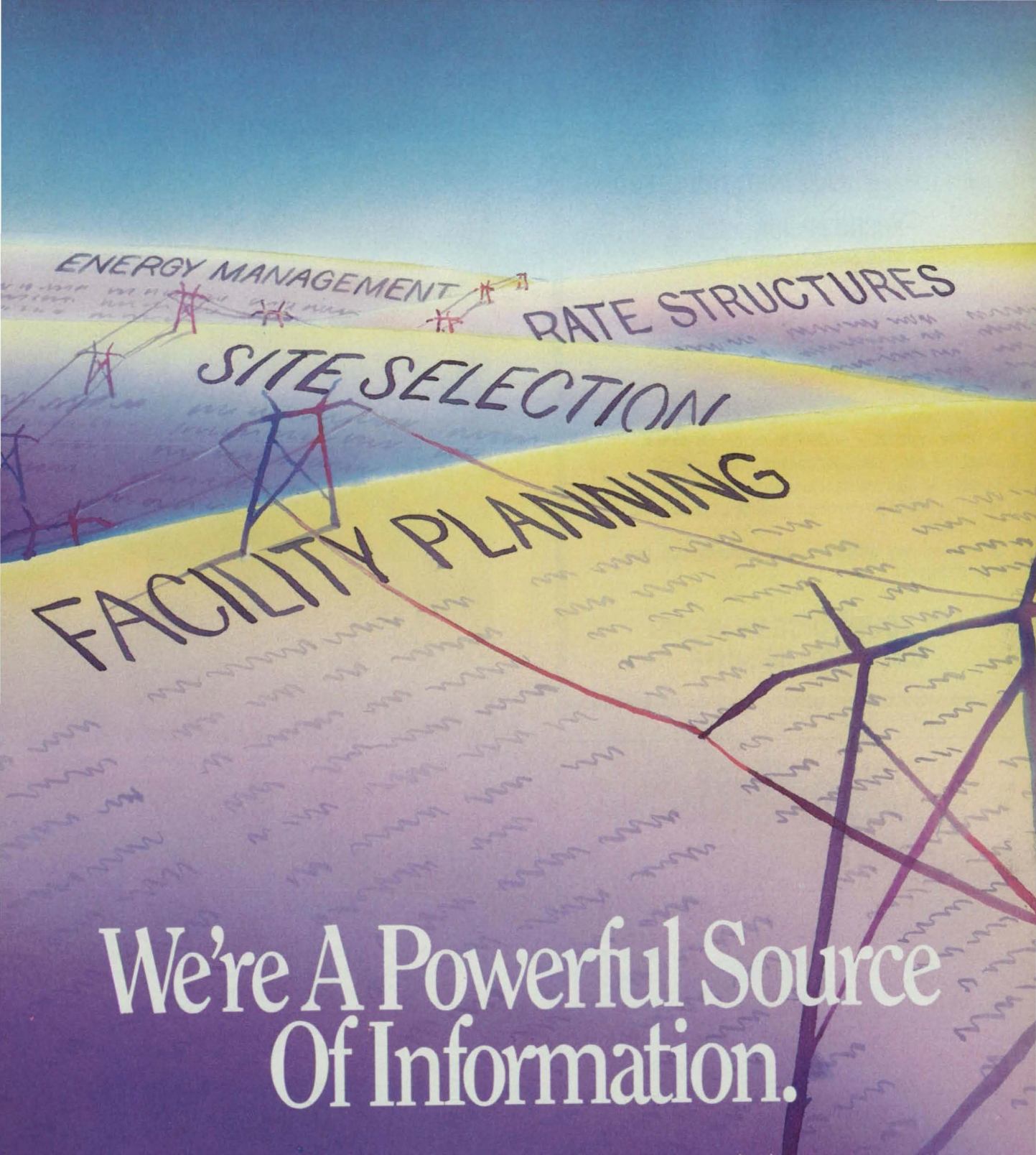
OPPORTUNITIES ON THE FINAL FRONTIER

Commercial space industry consists of several established and emerging markets, according to the findings of a Florida commission appointed to assess the state's potential in space. The most promising commercial segments of space industry are space transportation, remote sensing, satellite communications, materials processing, and space-based industrial facilities.

For now, the majority of space activities in Florida are a result of federal government operations—NASA's civil space programs and Department of Defense programs. Companies such as Martin Marietta (one of the state's largest industrial employers), McDonnell Douglas, Lockheed, Grumman, Honeywell, EG&G, and General Dynamics have thrived due to the abundance of federal contracts awarded in Florida.

BIG CHANCE FOR SMALL BUSINESS

Several small Florida companies are acting now to capitalize on the emerging opportunities of space. On November 17, 1988, a Titusville-based company, "E'Prime," had the distinction of launching the first commercial rocket from Cape



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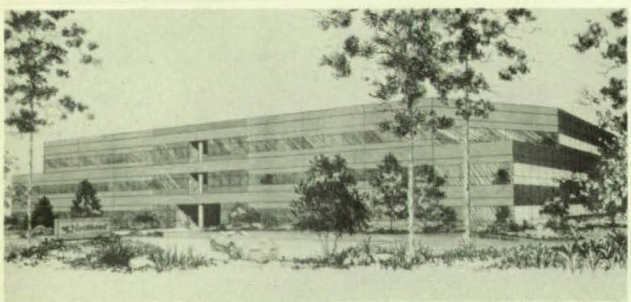
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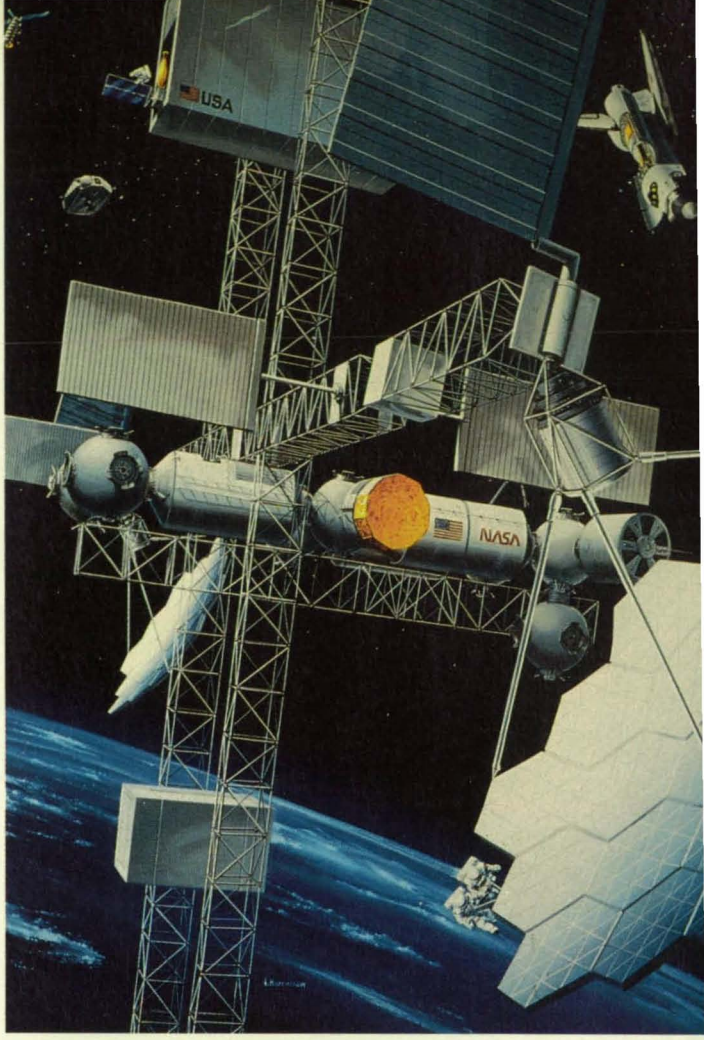
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Manufacturing and other commercial enterprises may soon find a new home in orbit around the Earth.
(Photo courtesy the Harris Corporation.)

Canaveral Air Force Station. That historic launch marked the beginning of the nation's commercial launch industry. This year, contracts for U.S. commercial rocket launches already represent over $1 billion. The vast majority of those launches will take place in Florida.

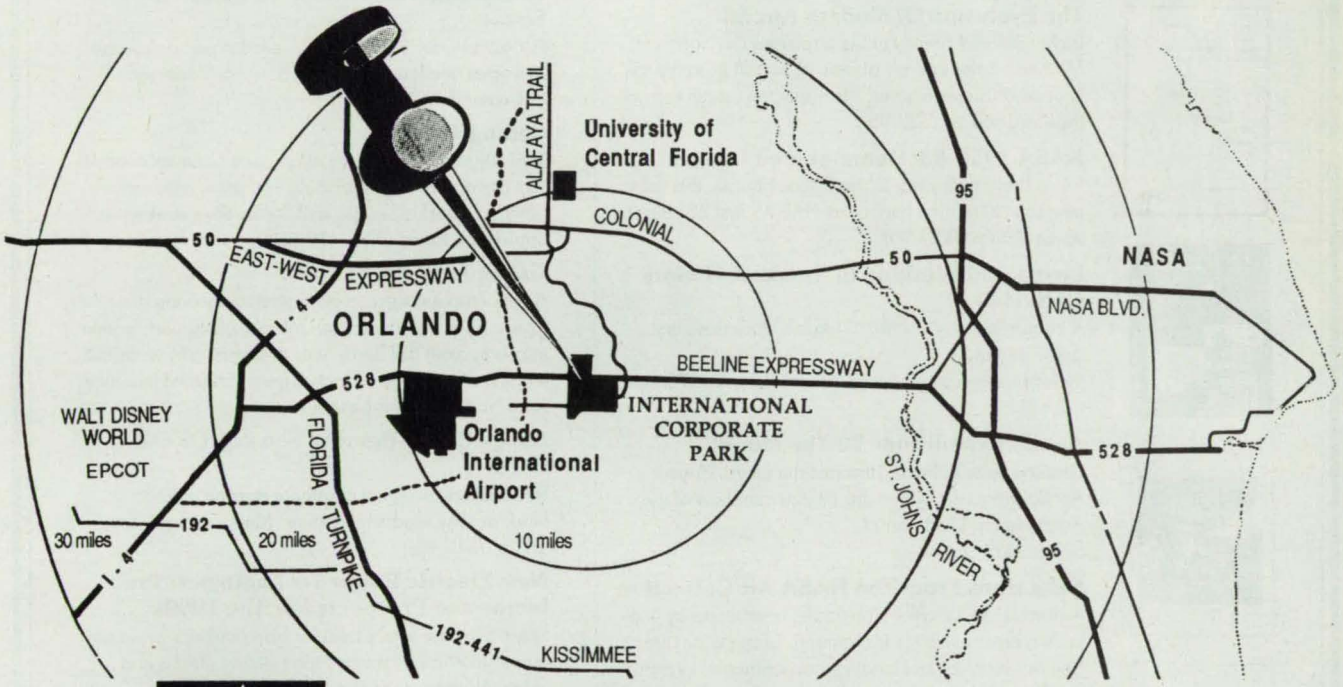
Another firm, Astrotech Space Operations, began with a retired aerospace engineer's idea to provide commercial processing services for Space Shuttle satellite payloads. After discussing the notion and receiving approval from NASA in 1982 and the subsequent search for investment partners, Astrotech opened its doors for business in 1984.

Today, after two buyouts, Astrotech is planning two multimillion dollar expansions. Astrotech's ownership is now controlled through a limited partnership between Wespace (a wholly owned subsidiary of Westinghouse) and Space Industries Inc. The Astrotech facility, besides being used extensively for payload and launch vehicle processing, eventually may be the manufacturing site for Wespace's Industrial Space Facility.

Florida's success as an incubator for innovative space business concepts can be attributed in part to its active network of referral and support for entrepreneurs and investors. An "entrepreneurial network" has been established by the Florida Department of Commerce in conjunction with approximately 30 private organizations, including several venture capital clubs, a Seed Capital Association, and a Venture Capital Council/Forum at the University of Miami, which is modeled after the MIT Enterprise Forum.

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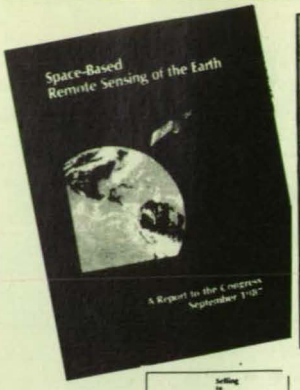
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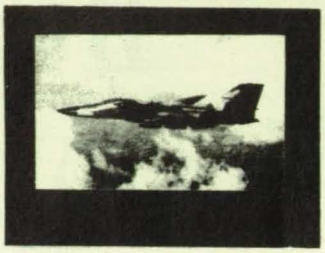














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Florida's economy is hotter than ever—a fact that's being recognized these days by corporations large and small. The Sunshine State leads the nation in new business start-ups and expansions of existing facilities, and tops the southeast in virtually every manufacturing category. Nationally, Florida ranked second in new manufacturing jobs created between 1976 and 1986, and by all indications, is tooling up for a decade that will be even more prosperous.

In a recent issue of *Market Trends,* two Florida cities were ranked among the top five high tech growth centers nationwide. The reason: Florida attracts the brightest minds, biggest contracts, and most notable corporate names in every aspect of high tech industry. In fact, a list of major companies which have found a place in the sun reads like a Fortune 500 roster.

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cluding wafer-scale integration. The project involves research in such disciplines as microelectronics, optoelectronics and superconductivity. It also includes development of advancd composite materials for use in high-temperature environments, such as aircraft propulsion systems and spacecraft hulls.

Florida will continue to benefit from developments in the Space Shuttle program, the National Aerospace Plane, the Strategic Defense Initiative, the Advanced Launch System, the International Space Station, the Industrial Space Facility, and the nation's first commercial launch site—Spaceport Florida.

GETTING AWAY FROM IT ALL

Work and school are not Florida's only high tech strong points. For those in business who yearn to get away from it all, Florida offers a permanent holiday from taxes and high costs. The Sunshine State is famous for its extremely low cost of living; no personal income tax; one of the nation's lowest corporate income tax rates; and housing and energy costs that are well below the national average.

Florida features 1,350 miles of sunny coastline that's always less than three hours away; an average annual temperature of 73 degrees; an abundance of scenic rivers, forests and parks; and historic, artistic, and cultural diversity that offers something for just about every interest.

There are more than 700 golf courses in Florida, and innumerable tennis courts. Florida is also headquarters to the Professional Golfers Association, and will soon host the Tournament Players Association. Several championship golf and tennis tournaments are held here each year.

Florida is home to two National Football League franchises—the Miami Dolphins and the Tampa Bay Buccaneers, in addition to a National Basketball Association team, the Miami Heat. As for baseball, 18 major league teams come to Florida every year for "Grapefruit League" spring training.

Florida's approach to staying at the forefront of high tech development is effective because it includes both business and personal considerations. Big business, entrepreneurship, research and development, education and lifestyle are components that define the Florida commitment to high tech enterprise.

HIGH TECHNOLOGY AND FLORIDA'S ECONOMY

Forty-five years ago Florida ranked last in the total number of manufacturing jobs in the south. Agriculture, tourism and construction were the dominant industries in a state that boasted a population of about two million. As was true with manufacturing, Florida had little involvement in national and international finance, industry, or trade.

Since then, Florida has experienced unparalleled growth in both population and economy. Today, with a population estimated at over 12 million, Florida is the fourth largest state in the nation, and its population is increasing by more than 1,000 people every day. An underlying reason for the state's successes since 1960 has been the increase in knowledge-based, technology-intensive manufacturing industry. Florida is now an international economic power, leading the southeast and ranked sixth in the nation in high tech employment. If Florida were a country, the size of its economy would exceed those of Australia and Spain.

High tech employment trends in Florida have mirrored the state's overall growth. Over the last decade, Florida's average annual growth rate for high tech firms has been consistently higher than that of the other ten largest high tech states. At current growth rates, Florida soon will rank fifth in high tech industry employment behind California, New York, Massachusetts and Texas.

Factors contributing to this growth include:

- re-emergence of the national space program;
- trends toward commercialization of space industry;
- concentration of engineers;
- industrial migration to Florida;
- expansion and development of quality engineering, science, and technology programs at Florida universities;
- a statewide proliferation of university-related research and development parks; and
- broad diversification of industries within the high tech classification.

Building on these strengths, Florida is moving toward the next decade with space age technology as a priority in its strategies for economic development.

Among Florida's burgeoning manufacturing industries, 27 percent of the total jobs are technology-intensive. High tech industry means jobs for over 150,000 Floridians with



Aerial view of Martin Marietta's defense industry plant in Central Florida.

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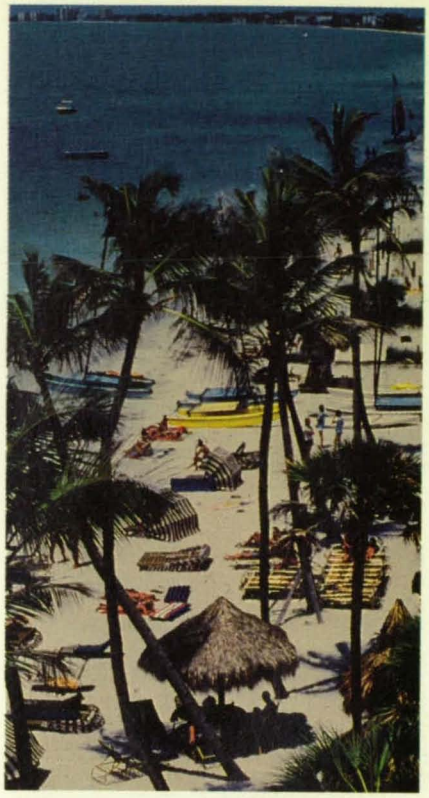
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2,100 high tech companies. Thanks to the recent growth in high tech manufacturing, Florida now ranks third in the nation in the number of new manufacturing jobs. This trend is expected to continue.

In addition to more and better jobs, Florida will hold other advantages:

- High tech products are value-added products, and are usually exported to other states or nations, resulting in a positive cash flow to Florida's economy.
- Wage rates in high tech industry are comparatively high, therefore promoting expansion in other sectors of the economy.
- High tech industry has a propensity to "spin-off" new firms and spawn entrepreneurial and industrial expansion. This has occurred, for example, in the laser-optics industry around Martin Marietta in Orlando, and in the computer industry around IBM in Palm Beach County.
- High tech industry works hand in hand with research institutions to the benefit of both, and cooperative research is vital to improving the competitiveness of American firms in the development and production of goods and services.

A robust industry/university research and development partnership creates new technologies, and equally important, contributes to the state's pool of skilled scientists and engineers, providing for the labor needs of high tech industry.



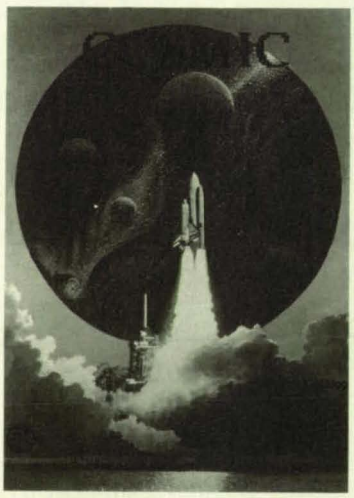
Palm trees and ocean breezes are natural recruitment tools for attracting employees to Florida.
(Photo courtesy Florida Department of Commerce, Division of Tourism.)

EMERGING HIGH TECH INDUSTRIES

Several emerging high tech industries receive special attention in Florida. The 1986 Legislature directed the state's Board of Regents, in conjunction with the Florida High Technology and Industry Council, to report on the identified fields that will have a clear relevance to and impact on Florida's high tech economic future. Their report focused on seven specific fields, and on various levels of related research and development at universities in the state.

Biomedical devices are the products of advanced technology applied to medical care. The classification includes pharmaceutical preparation, X-ray apparatus, surgical, orthopedic and ophthalmic goods, and medical electronic

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devices (including pacemakers, difibrilators, neural stimulators, electrosurgical systems, electrocardiograms, magnetoresonance imaging and CAT scan technology).

This field represents a national market of more than $50 billion annually, with a growth rate in excess of ten percent per year. Florida, especially South Florida, enjoys a leadership role in related commercial enterprises. Biomedical research and development programs in the state are located at the University of Miami, the University of South Florida, Florida International University, and the University of Florida.

One tangible result of the innovative research being conducted is a product called "bioglass." Developed at the University of Florida, bioglass is an inorganic material which bonds to human bone tissue. Bioglass has been used successfully to reconstruct the inner ear and restore hearing to deaf patients.

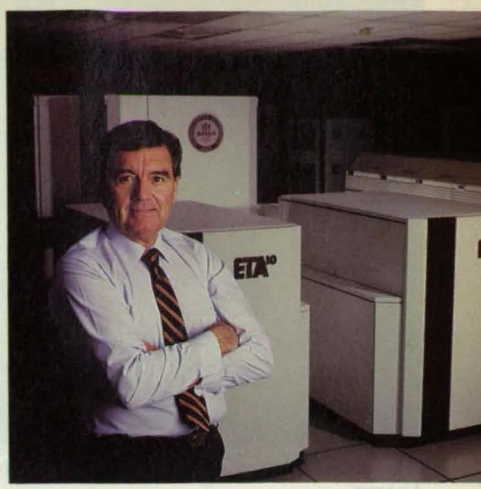
Biotechnology is the application of knowledge gained in research on life processes. Its areas of economic importance include health care and maintenance, genetic engineering, plant agriculture and forestry, animal agriculture, marine industries, food processing, and environmental applications.

Perhaps more than any other high tech sector, the origins of the biotechnological activities throughout the United States are university based. Several Florida universities have initiated quality programs in one or more of the fields listed above. Research and development in biotechnology is concentrated at Florida State University, the University of Florida, Florida A&M University, the University of Miami, and the University of South Florida.

Basic research is centered at Florida State University through the Center of Multi-Disciplinary Biotechnology, with programs in the basic sciences of genetics, biochemistry, immunology and bioprocess engineering (organized through the FAMU/FSU College of Engineering).

Computer Science and Software have experienced a period of explosive growth, both in educational and commercial utilization. The industry's primary objectives include development of efficient and low-cost software, and new computer concepts. Pioneering research and development programs are conducted at Florida State University, the University of Florida, the University of Central Florida, Florida International University, the University of Miami, and Florida Atlantic University.

In early 1987, Florida State University began installation of the world' s first Class VII supercomputer—the Cray ETA 10, the fastest and largest computer on Earth. Under the auspices of the Supercomputer Computations Research Institute



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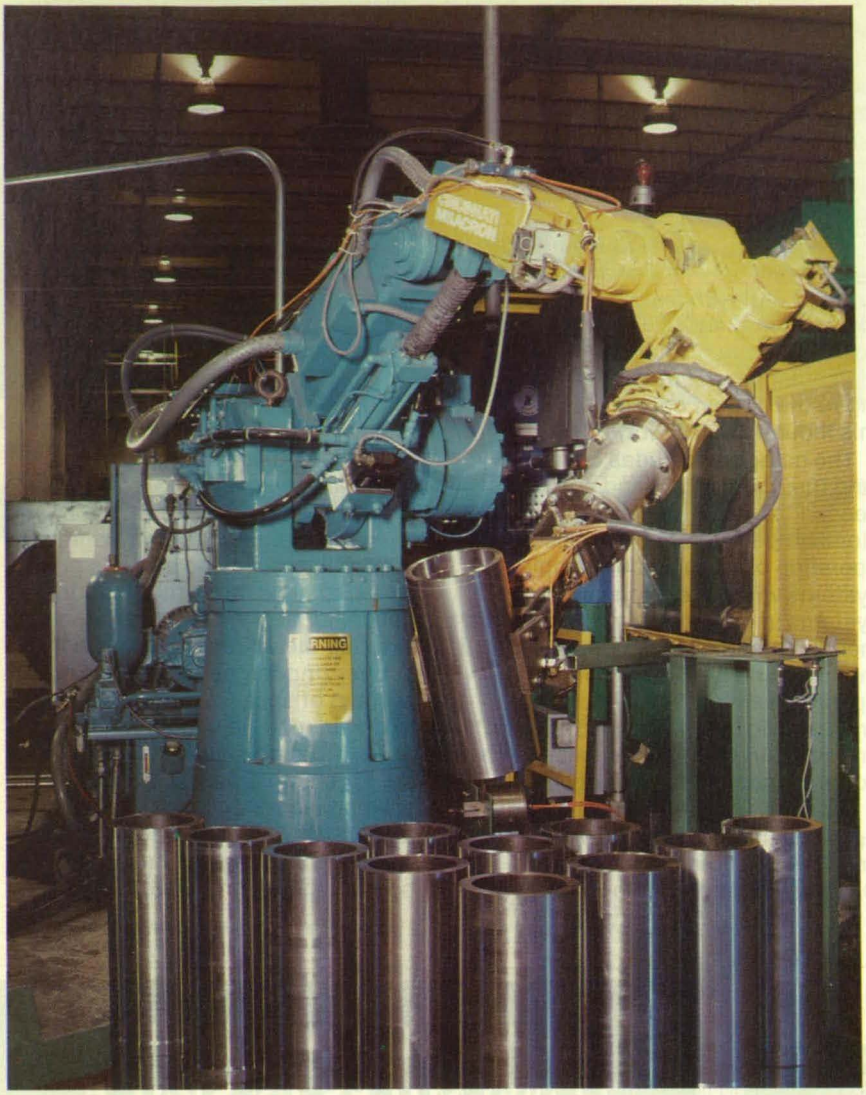
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In 1985, the Florida Legislature began funding programs in materials science at the University of Florida and Florida State University. At Florida State University, the program is called MARTECH (Materials Research and Technology), while at the University of Florida the program is called Microfabritech.

These programs and others around the state sponsor research in superconductivity (through FSU's superconducting linear accelerator), modification of materials in a variety of classifications, novel syntheses, electro-optics, compositionally modulated materials, and atomically engineered materials.

The Florida Initiative in Advanced Microelectronics & Materials, sponsored by the Department of Defense, was initiated in 1988 by the State University System through a $25 million grant (the largest in the state's history). The initiative will include statewide R&D in microelectronics, optoelectronics, superconductivity, and composite materials.

Robotics in action on a Copperhead production line at Martin Marietta.

WHAT'S WHERE WITH FLORIDA'S HIGH TECH INDUSTRY

No one part of Florida has a monopoly on high tech industrial growth. The state's six regions feature different concentrations of high tech industry, from aviation and aerospace to computers.

Northwest Florida

Defense spending is the key to high tech development in the Florida Panhandle, which hosts 13 military installations. Cities such as Fort Walton Beach, Pensacola and Panama City were home to more than five hundred defense related firms in 1987. Communications equipment, electronic components, computer software and measuring equipment round out Northwest Florida's high tech contributions to the state's economy.

North Florida

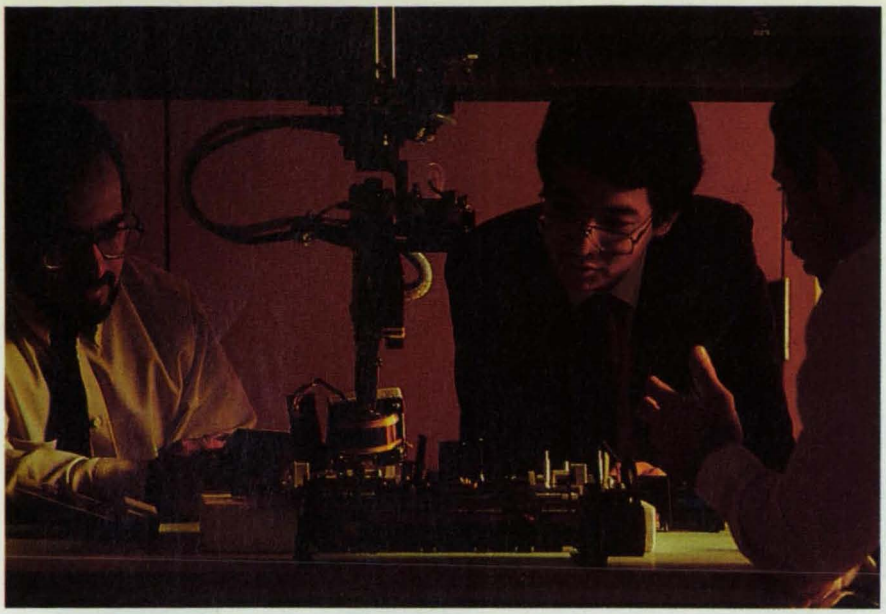
Besides being one of the nation's busiest port cities, Jacksonville was home to Florida's highest number of defense contractors in 1987, with 286 firms. Products from this area include aircraft parts, computer software, surgical instruments and ophthalmic goods.

The University of Florida in Gainesville has a history of close cooperation with high tech industry. Headquartered at the university is NASA's Southern Technology Application Center (STAC), which specializes in researching the patent potential of new inventions. Recognizing that small high tech companies are often frustrated by the intricate procedures and major expense involved in patent application, STAC offers product potentiality studies to shortcut the process. Using NASA's RECON database as a starting point, the STAC staff searches through existing patents to assess whether or not a new idea can be patented. The innovator must still consult an attorney, but much of the work has already been done by STAC.

Central Florida

Central Florida's Brevard, Orange, Seminole and Volusia counties comprise the Space Coast, which accounts for a vast majority of Florida's guided missile and space vehicle industry. In 1987 this area contained 36 percent of the state's high tech employment and 20 percent of its technology-intensive firms.

The cities surrounding NASA's Kennedy Space Center, Patrick Air Force Base and Cape Canaveral Air Force Station have experienced tremendeous growth since the nation's space program was born there in the 1950s. Today, with the Space



Robotics research at Florida International University in Miami.

Shuttle's return to operation and the growth of commercial space enterprise, up to 38 percent of Brevard County's total employment is in space-related industry and services.

The Space Coast also has emerged as a world leader in the development and manufacture of simulation training devices and electro-optics. Research in these innovative fields takes place at the University of Central Florida's Institute for Simulation and Training and Center for Electro-optics and Laser Research.

Gulf Coast

Florida's western coast—primarily the counties surrounding Tampa Bay—is becoming an important center for high technology business. The area's major cities, St. Petersburg, Tampa, and Clearwater, are home to approximately 700 firms doing business in computers, telecommunications, electronics, aircraft/missile guidance components, industrial robots, defense simulators and data recorders.

The Tampa/St. Petersburg area hosts one public university, 26 private colleges and universities, five public community colleges and nine public vocational/technical centers. This region's high tech employment has grown 49 percent over the past five years.

Southeast Florida

Southeast Florida, including Dade, Broward and Palm Beach counties, is otherwise known as the Computer Coast. These counties accounted for 40 percent of the state's high tech employment and 33 percent of its high tech firms in 1987. This area's industry is focused on computing equipment, aircraft, and pharmaceuticals.

Palm Beach County has the largest concentration of computer and communications-related industry in Florida. High tech firms in Palm Beach numbered 330 in 1987, with IBM's facility alone employing 8,000. This region also is home to three-quarters of Florida's pharmaceuticals industry, and has developed a significant portion of the medical equipment industry.

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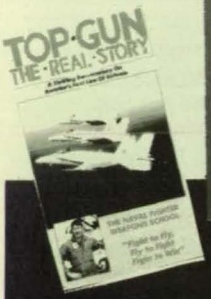
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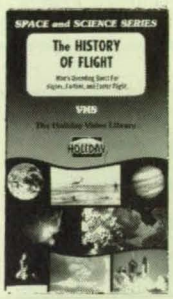
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B-17: The Flying Fortress
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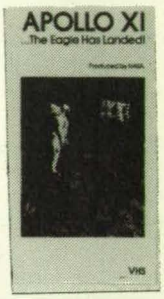
The History Of Flight
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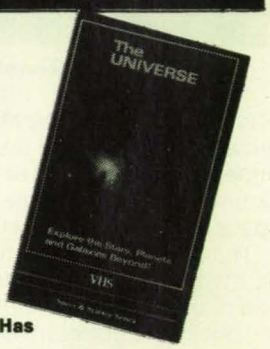


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Speechviewer, a product designed to help those with speech and hearing disabilities, was developed in Boca Raton by an IBM group called Special Needs Systems.

Southwest Florida

Medical computer software, financial data processing and avionics are the high tech highlights for Southwest Florida, the fastest growing area in the state. The region has four colleges and universities, including a branch campus of the University of South Florida. Edison Community College has the largest endowment of any junior college in the country, helping it to maintain leading edge technology programs such as robotics.

Florida is a high growth state in every aspect of the word. Opportunities in high tech industry have combined with the state's fertile business climate to create one of the nation's best profit environments. Florida's economic momentum is carrying the state into the 1990s with sights set high for the 21st century.



Biotechnological research at Florida universities promises positive results for advanced agricultural engineering.

SOURCES: Building Florida's Future, a report to the Florida Legislature from the Board of Regents and the Florida High Technology and Industry Council, 1987.
Florida Department of Commerce, Division of Economic Development.

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(Continued from page 50)
directly, sending pressurized hydraulic fluid to a hydraulic motor coupled to a rotating alternator. Both concepts will be evaluated, and one will be selected for final design, assembly, and testing.

This work was done by Richard K. Shaltens of **Lewis Research Center**. *Further information may be found in NASA TM-88897 [N87-15031/NSP], "Advanced Stirling Conversion Systems for Terrestrial Applications."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14558

Piloted Simulations of a V/STOL Aircraft

Flight and control characteristics are evaluated.

A report describes simulated flight tests to evaluate the handling qualities and flight characteristics of the Grumman Design 698 aircraft, a vertical and short takeoff and landing (V/STOL) aircraft. The tests were performed by pilots in the vertical motion simulator at Ames Research Center.

The tests showed that a classical control system is adequate for landing on a destroyer in moderate seas and on an aircraft carrier in heavy seas, as well as for the relatively simple task of landing vertically on a fixed pad. The classical control system, based on single-axis control laws, provides individual control of pitch, roll, and yaw with aerodynamic surfaces, vanes, and changes in engine thrust and nacelle tilt. In addition, a modern control system has been designed for the aircraft; it is a direct digital integrated flight-propulsion controller that gives the pilot uncoupled velocity control and attitude control.

Although the simulation pilots had diverse backgrounds, all of them mastered the aircraft with the classical control system. The pilots who had no previous V/STOL experience learned quickly.

According to pilots' ratings and measurements of the performance of the control system, a precision mode of flight control would be needed on a demonstrator or production version of the aircraft. In addition, an unusual characteristic of the aircraft would have to be eliminated: adverse-nonminimum-phase acceleration, in which a negative acceleration is the first result of a pilot's control input.

The two-engine aircraft should incorporate cross-shafting so that a portion of the thrust of one engine can be transferred to the other. Cross-shafting will reduce the recovery speed and the loss of altitude and improve capability for safe ejection of the pilot in cases of engine failure. In either case, during a powered approach the pilot should attempt to maximize the flight time above the minimum recovery speed and above the minimum altitude loss, thus minimizing the flight time below these speed and altitude limits.

This work was done by Megan A. Eskey and Samuel B. Wilson III of **Ames Research Center**. *Further information may be found in NASA TM-86785 [N87-12558/NSP], report "The Handling Qualities and Flight Characteristics of the Grumman Design 698 Simulated Twin-Engine Tilt Nacelle V/STOL Aircraft."*

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Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 18]. Refer to ARC-11807.

Assessment of Semi-Empirical Dynamic Stall Models for Turboprop Stall Calculations

Three semiempirical models are compared.

A report presents the comparison of stall-flutter responses obtained from three semiempirical dynamic stall models. The study is part of an effort to develop models for the stall-flutter analysis of highly loaded propellers (advanced turboprops).

Under normal conditions, the blade sections of a conventional propeller are at low angles of attack, the flutter speed is high, and generally there is an appreciable margin of safety between the operating speed and the flutter speed. However, during the takeoff period, the blade sections may operate at high angles of attack and could be subjected to stall flutter, a self-sustained vibration in a periodically separated flow. The flutter speed at this condition is very low, and stall flutter affects the fatigue life of the turboprop. Hence, the prediction of the stall flutter speed is critical in design, and an appropriate method of analysis of stall flutter is necessary for research.

The prediction of flutter speeds at low angles of attack (classical flutter) for advanced turboprops has been performed by modifying the existing analysis methods. However, studies of stall flutter have been few and mostly empirical because of the complexity in modeling periodically separated flows.

In the report, the available models of dynamic stall are applied to simple structural models to study the extent of their validity and to select an appropriate model for application to advanced turboprops. Three models of dynamic stall are used together with typical section and plate structural models. The models are compared with respect to their predictions of lift and moment hysteresis loops, predictions of limit cycles, ease of implementation, and the feasibility of developing the corresponding stall models for arbitrary airfoils. A plate model in conjunction with its normal vibrational modes is considered to explore whether the analytical integration of the loads in the spanwise direction is feasible. The numerical study is performed for a single blade, and cascade effects are not included. The analysis of response includes both plunging and pitching motions of the blade.

In model A, a correction is applied to the angle of attack when the angle of attack exceeds the static stall angle. In model B, a synthesis procedure is used for angles of attack above static stall angles, and the effects of history are accounted through the Wagner function. In both models, the lift and moment coefficients for angles of attack below stall are obtained from tabular data for a given Mach number and angle of attack.

In model C, the lift and moment coefficients are given in the form of two differential equations, one for angles below stall and the other for angles above stall. The parameters of these equations are nonlinear functions of the angle of attack. The effects of vortex shedding, an important feature of dynamic stall, are not considered in model A, accurately considered in model B, and approximately considered in model C.

Model C involves fewer parameters than does model B. Model A involves only one empirical parameter but must be tested on advanced turboprop airfoils and on high-frequency, low-amplitude oscillations. The differential form of model C may render it suitable for use in linearized analyses of stability.

One conclusion reached during the study is that the operating environment of an advanced turboprop (high-frequency, low-amplitude oscillations; sweep; and high subsonic speed) favors the conditions of light stall, in which loads induced by vortexes are not severe. Therefore, simple models like A and C can be used to analyze stall flutter and advanced turboprops.

This work was done by K. R. V. Kaza of **Lewis Research Center** *and T. S. R. Reddy of the University of Toledo. Further information may be found in NASA TM-88917 [N87-18883/NSP], "A Comparative Study of Some Dynamic Stall Models."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14657

Fabrication Technology

Hardware Techniques, and Processes

78 Photopolymerization of Levitated Droplets
79 Semiempirical Model Would Control Czochralski Process
79 Gas-Jet Cooling Would Improve Czochralski Process
80 Grinding Parts for Automatic Welding

Photopolymerization of Levitated Droplets

Microspheres of controllable composition are made rapidly.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experimental containerless process combines two established techniques to make a variety of polymeric microspheres. In a single step, electrostatically-levitated monomer droplets are polymerized by ultraviolet light. The process is faster than the multiple-step emulsion polymerization process now used to make microspheres.

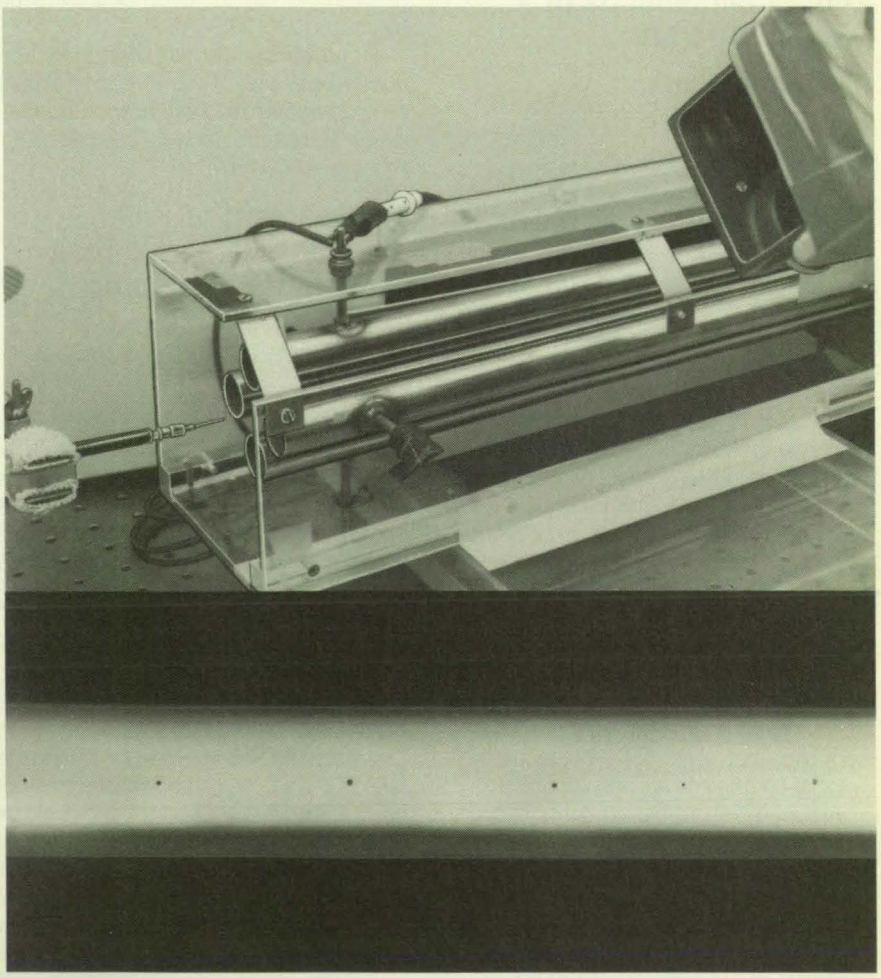
Electrically-charged liquid droplets are prepared by a commercial or laboratory droplet generator. The droplets can include a monomer or a mixture of monomers. Optional ingredients include additives to speed polymerization, magnetic particles, fluorescent dyes, proteins, catalysts, and blowing agents to induce porosity.

The droplets are suspended in a cylindrical quadrupole electrostatic levitator (see figure). An alternating electrostatic field produces a dynamic potential well along the axis. Many dense droplets up to a few microns in diameter can be suspended along the axis without clumping. The ac voltage required for levitation depends on the droplet charge-to-mass ratio and is typically about 3 kV.

The suspended droplets are irradiated with ultraviolet light, which causes them to polymerize into solid beads. The polymerization time depends on the ingredients and the ultraviolet intensity; in preliminary experiments, it took a few minutes. The microspheres can be made unusually pure, not only because the process is containerless but also because no solvents or other reactants are necessary for polymerization.

By the choice of ingredients and particle size, it is expected that the process will enable the tailoring of microspheres for medical, scientific, and industrial applications. These may include the following:

- The magnetic separation of cancer cells;
- The labeling and visualization of cellular structures by optical or electron microscopy;
- Porous beads serving as large-surface-area catalysts or catalyst supports;
- Affinity chromatography requiring uniform microspheres;
- The calibration of sieves and particle-measuring instruments;
- Magnetic coatings for data storage; and
- Diagnosis, therapy, or drug targeting by means of timed-release beads and/or beads guided into position with magnets.



In the **Quadrupole Electrostatic Levitator** (above), droplets to be polymerized are suspended along the axis (below).

This work was done by Alan Rembaum, Won-Kyu Rhim, Michael T. Hyson, and Manchium Chang of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 152 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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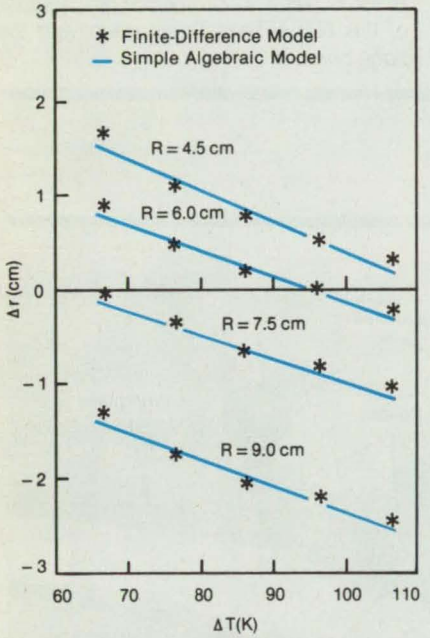
Refer to NPO-16551, volume and number of this NASA Tech Briefs *issue, and the page number.*

Semiempirical Model Would Control Czochralski Process

Simple equations relate processing conditions.

NASA's Jet Propulsion Laboratory, Pasadena, California

A semiempirical mathematical model has been proposed for the control of the growth of single crystals of silicon by the Czochralski process. The model expresses the dependence of the pulling rate and the shape of the liquid/solid interface upon the important process variables; namely, the radius of the growing crystal, the temperature of the crucible, the level of the melt, and the height of the exposed portion of the wall of the crucible. It is necessary to control the shape of the interface in a manner consistent with the other variables, to maintain a radially uniform concentration of dopant, and to reduce thermally induced stresses in the vicinity of the interface.



A **Simple Algebraic Model** and a computerized finite-difference model were used to predict the convexity (negative Δr) or concavity (positive Δr) of a crystal-growth interface at various crystal radii and temperature differences.

The Czochralski process is dominated by the conductive transfer of heat inside the melt and crystal; by the radiative transfer of heat to and from the surfaces of the melt, crucible, and crystal; and, to a lesser extent, by convection in the melt. The thermal environment near the interface changes during growth because the level of the melt falls, exposing more of the wall. Thus, to grow a crystal of the required diameter while maintaining the required shape of the interface, it is necessary to adjust both the heating power (to affect the temperature of the crucible) and the pulling speed according to a mathematical model of the process to compensate for the changing conditions.

The equations are derived from basic considerations of the transfer of heat across all the affected surfaces. In this analysis, convection is ignored, and the melt is assumed to have a uniform temperature. The equations are

$$v = (A - B_1 h_c \Delta T)/R - B_2 \Delta T/h$$
$$h = h_o - (\rho_c/\rho_m)(R/R_c)^2 L$$
$$h_c = h_o - h + h_{co}$$
$$\Delta r = (a_1 - a_2 \Delta T)R - (b_1 - b_2 \Delta T)R^2$$

where v = the pulling speed; ΔT = the difference between the temperatures of the melt and the crystal; R = the radius of the crystal; h and h_o represent the present and initial heights of the surface of the melt, respectively; h_c and h_{co} represent the present and initial heights of the exposed portion of the wall of the crucible, respectively; L = the total distance through which the crystal has been pulled; R_c = the radius of the crucible; ρ_c and ρ_m represent the densities of the crystal and melt, respectively; Δr = the difference in height between the center and the edge of the interface; and a_1, A_1, a_2, A_2, b_1, B_1, b_2, and B_2 are constant parameters that are found by fitting the equations to measurements from the crystal-growing apparatus to be controlled or to the predictions of a more-complete thermal analysis.

The equations were compared with the results of such an analysis that was performed with a conduction-dominated finite-element model. Because the equations fit the predictions so well, they might be used to simulate complete growth cycles without requiring the excessive computer time that would be consumed by rigorous finite-element modeling.

This work was done by M. P. Dudukovic, P. A. Ramachandran, and R. K. Srivastava of Washington University for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 41 on the TSP Request Card.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C 2457(f)], to Washington University. Inquiries concerning licenses for its commercial development should be addressed to

Washington University
Chemical Engineering
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One Brookings Drive
St. Louis, MO 63130

Refer to NPO-17271, volume and number of this NASA Tech Briefs *issue, and the page number.*

Gas-Jet Cooling Would Improve Czochralski Process

The diameter of the growing crystal would be more stable and controllable.

NASA's Jet Propulsion Laboratory, Pasadena, California

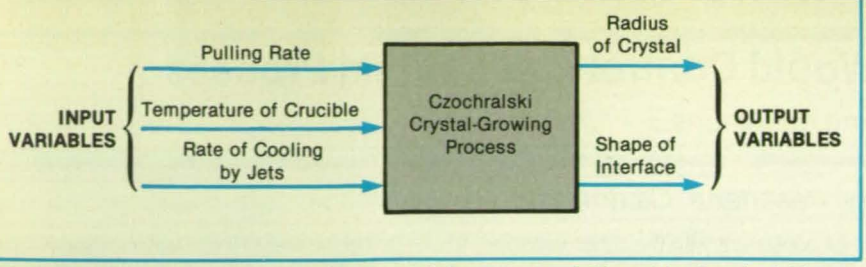
Controlled cooling by jets of gas would improve the growth of single crystals of silicon by the Czochralski process, according to a recent theoretical study. The rate of cooling by jets thus joins the temperature of the crucible and the pulling rate as an input variable of the process that can be adjusted to achieve the required diameter of the crystal and shape of the crystal/melt interface (see figure).

The mathematical model of the process takes account of the following major thermal effects in the vicinity of the interface:

- The conduction of heat from the interface into the crystal,
- The conduction of heat from the melt across the interface into the crystal,
- Convective cooling of the crystal and of the surface of the melt by the jets of gas blowing horizontally just above the wall of the crucible, and
- Radiative cooling of the side of the crystal.

In addition, the calculations include the effects of the pulling speed, the shape of the crystal/melt interface, and the shape of the melt/gas meniscus. The effects of convection in the melt and of the rotation of the crystal are ignored.

Both simple analytical approximations and detailed numerical simulations show that cooling by jets offers some important advantages: It can increase the pulling rate at a given diameter, thus increasing productivity. The shape of the interface and the diameter are more stable than in a system without jets, and either can be controlled solely by adjusting the rate of flow through the jets. In addition, the control of the shape of the interface and the diameter



The **Critical Parameters of the Growing Crystal** (the output variables of the Czochralski process) can be controlled via two or all three of the input variables. One of the input variables (usually pulling speed) can be held constant while the other two are adjusted to achieve the required diameter and interface.

by varying the flow rate is more effective than control through adjustment of the pulling rate or of the temperature of the crucible. Furthermore, both the shape of the interface and the diameter can be controlled simultaneously by adjusting the flow rate and either the temperature or the pulling rate.

To achieve uniform doping of the crystal, it is necessary to maintain a planar interface. One of the disadvantages of cooling by jets is a tendency to produce concave interfaces. Other disadvantages include difficulties in maintaining axisymmetry and localized high thermal gradients, which increase thermal stresses and, consequently, give rise to dislocations in the crystal. The concavity of the interface can be minimized by controlling all three input variables. Axisymmetry can be promoted by the use of multiple jets around the crystal. The flow of gas will probably have to be restricted to moderate levels to realize all of its potential benefits.

This work was done by M. P. Dudukovic, P. A. Ramachandran, and R. K. Srivastava of Washington University for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 71 on the TSP Request Card.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C 2457(f)], to Washington University. Inquiries concerning licenses for its commercial development should be addressed to

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Refer to NPO-17272, volume and number of this NASA Tech Briefs *issue, and the page number.*

Grinding Parts for Automatic Welding

Rollers guide a grinding tool along the prospective welding path.

Marshall Space Flight Center, Alabama

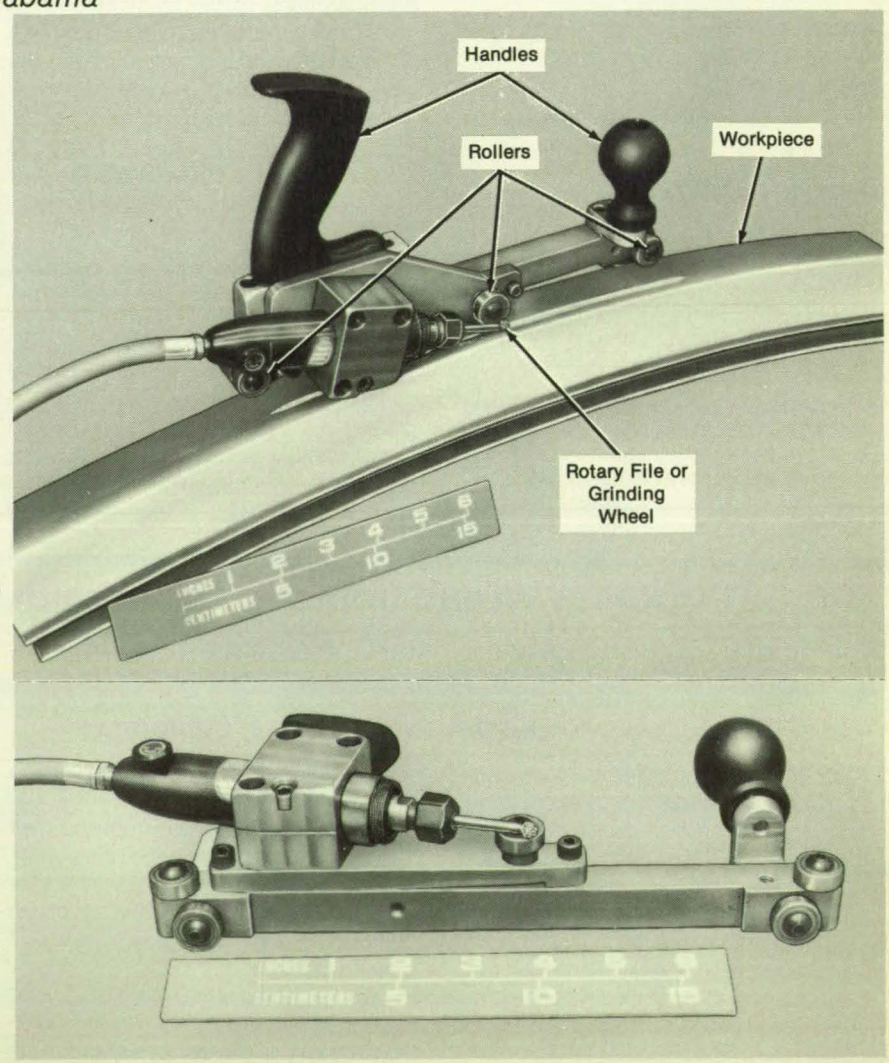
A skatelike fixture holds a rotary grinder or file for machining large-diameter rings or ring segments in preparation for welding. The fixture-mounted grinder machines the surface to a quality sufficient for automatic welding; manual welding with its attendant variations and distortion is not necessary. The fixture was developed to enable the automatic welding of parts, the manual welding of which had resulted in a weld bead permeated with microscopic fissures.

An operator moves the fixture around the circumference of the workpiece to be welded. As the fixture is moved, the air-driven rotary grinder removes material to a preset, adjustable depth.

The fixture moves on five rollers that maintain a fixed relationship with the workpiece, thereby ensuring precise machining (see figure). A pair of rollers guides the fixture around the periphery of the workpiece. Another pair rides on an edge to control the lateral position of the cutter. The fifth roller prevents the fixture from cocking.

This work was done by Richard K. Burley and William S. Hoult of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 18]. Refer to MFS-29329.



The **Operator Grasps Handles** to push the rolling fixture along the part. Rollers maintain a precise dimensional relationship so that the grinding wheel can cut to a precise depth.

Mathematics and Information Sciences

Hardware Techniques, and Processes

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Books and Reports

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Managing Data From Signal-Propagation Experiments

Computer programs generate characteristic plots from amplitudes and phases.

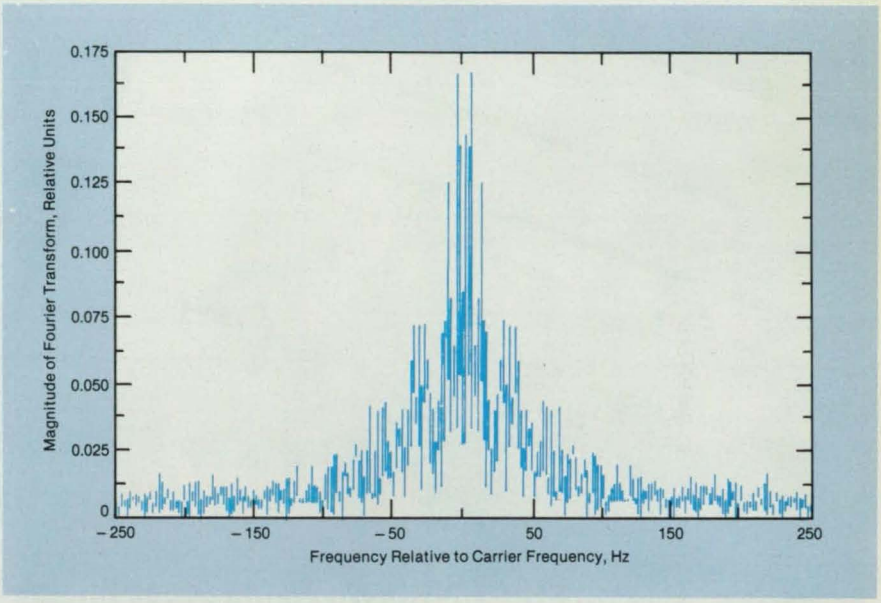
NASA's Jet Propulsion Laboratory, Pasadena, California

A software system enables a minicomputer to process data on the amplitudes and phases of signals received during experiments in ground-mobile/satellite radio propagation. The system takes advantage of the file-handling capabilities of the UNIX operating system and the C programming language. The system interacts with the user, under whose guidance programs in the FORTRAN language generate plots of spectra or other curves of the types commonly used to characterize signals.

In the particular experiments for which the system was devised, signals received at 896 MHz are split into an in-phase channel and a quadrature channel, in each of which the amplitude is sampled 1,000 times per second. With the help of a calibration table, these raw data are preprocessed into equivalent data on the power (or amplitude) and phase.

The preprocessed data are organized into files, each of which consists of a sequence of 63 records of 4,120 bytes or 2,060 integers apiece. Each record contains a sequence of 1,024 samples (thus representing 1.024 s of observation time). In addition to the amplitudes and phases, each record also contains a 24-byte or 12-integer header that specifies such ancillary parameters as the type of antenna, the time of day, and the speed of the receiving vehicle.

For efficiency, the files are stored in binary format and must be converted to the ASCII format for display or for further processing. A small program in the C language can be used to convert these or any binary sequential files into the equivalent ASCII files.



The Fourier Transform, a measure of the amplitude spectrum, is computed from a sequence of 1,024 in-phase and quadrature samples of the input signal.

Typically, a researcher needs only those records having specified values or ranges of values of the ancillary parameters (e.g., pertaining to a certain type of antenna or to a certain interval of time). An interactive program in the C language called "Parafile" operates in conjunction with the program "Paracomp" to extract the amplitude and phase information of only such records from a file while ignoring the other records. The output of these file-handling programs is a combination of two files: one containing the amplitudes or powers, the other containing the phases.

FORTRAN programs are used to process the file-handling outputs into any of several useful forms. FORTRAN program 1 computes the probability that the power of the signal equals or exceeds a specified level. FORTRAN program 2 computes the probability density of the signal level and fits a Rician density function to the data points via a least-squares fitting algorithm. Program 3 computes the frequency of the duration of fade. Program 4 computes Fourier transforms of the first 1,024 samples of the input file (see figure).

This work was done by A. V. Kantak of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 86 on the TSP Request Card.*
NPO-17232

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Scheduling Tasks in Parallel Processing

Algorithms are sought to minimize the time and cost of computation.

A report describes research on the scheduling of computational tasks in a system of multiple identical data processors operating in parallel. To take advantage of parallelism, tasks should be distributed over as many processors as possible. However, the overhead of communication among distributed tasks may outweigh the improvement in performance achieved through the use of multiple processors. The requirement that some tasks be completed before others are begun limits further the degree to which parallel proces-

sors can be employed effectively.

The effectiveness of a given assignment of tasks is measured in terms of two numerical criteria: the cost of communication based on the total exchange of data among tasks and the total execution time. If no processor is idle until it has completed all its tasks, then the total execution time of the system is simply the total execution time on the most-heavily-loaded processor. The strategy in assignment is to minimize a weighted sum of these communication and execution costs.

The computational intractability of this problem in minimization requires the use of suboptimal heuristic algorithms in all but the most trivial cases. The authors describe four such methods.

The first, called the "list heuristic," is a variation on classical list scheduling. In the first phase of the list heuristic algorithm, tasks are sorted in order of increasing total communication. The rationale is that because the assignment of the first tasks will not be based on costs of communication with other tasks, they should be the tasks that communicate the least, so that in scheduling one ignores as little information as possible. In the second phase, a feasible partial solution is iteratively expanded into a complete schedule. Each task from the ordered list is scheduled on a processor at the earliest time, such that communication with assigned tasks is minimized and such that constraints on precedence are not violated.

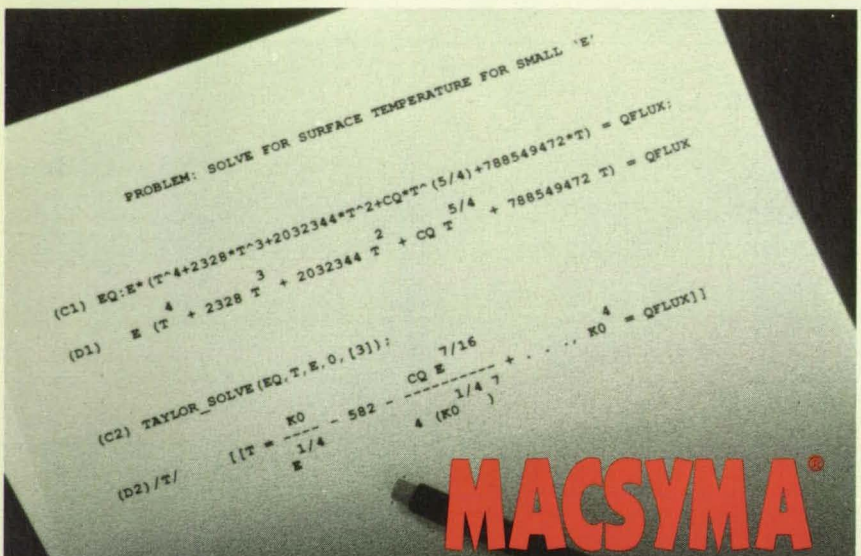
The second algorithm, called the "cluster heuristic," can be applied to tightly coupled tasks and consists of four phases. In the first phase, a list is made of pairs of tasks that communicate, and the list is sorted in order of decreasing pairwise communication, so that tightly coupled tasks are considered first during the next phase. In the second phase, n clusters of tasks are built; a cluster is associated with each processor. As pairs of tasks are considered, if neither task is assigned, both are placed on the least-loaded processor (i.e., in the smallest cluster). If one task is assigned, the other is assigned to the same processor unless a specified load threshold has been exceeded, and in that case it is placed on the least-loaded processor. Load balancing is intended to prevent large clusters that would result in the poor utilization of parallel processing.

In the third phase, the tasks within each cluster are ordered with respect to the constraints on precedence, so that each cluster represents a feasible sequence of tasks. In the fourth phase, subsequences of tasks are shifted to later times to enforce the constraints on precedence among tasks that belong to different clusters.

The third algorithm, called the "exchange heuristic," is an iterative-improvement algorithm that may begin with any initial feasible assignment of tasks to processors and periods of time. Pairwise exchanges of tasks are then performed (with the goal of decreasing the costs of communication) until no further advantageous exchanges are possible, a principle that has been used successfully in solving the traveling-salesman problem and other classical combinatorial problems. At each iteration, a selection is made of that pair, the exchange of which would yield the greatest improvement in the objective. The exchange is made if the constraints on precedence are not violated.

The fourth algorithm is an iterative one for the optimal assignment of tasks and is based on a concept called "simulated annealing" because of its mathematical resemblance to aspects of physical annealing processes. A conventional iterative algorithm usually converges to a local optimum (as measured by the weighted-cost function). In anticipation of finding a more global optimum, the simulated-annealing algorithm probabilistically accepts configurations of assignments that temporarily degrade the quality of the system.

The acceptance probability is a function of the change in the cost function and a parameter analogous to the temperature in a physical annealing system. As the parameter is slowly reduced, fewer nonimproving changes are accepted. Thus, a coarse global search evolves into a fine local search for optimality, and the probabilistic



"jumps" provide escapes from nonglobal optima.

This work was done by Camille C. Price of Stephen F. Austin State University and Moktar A. Salama of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Scheduling of Precedence-Constrained Tasks on Multiprocessors," Circle 40 on the TSP Request Card.*
NPO-17219

Statistical Analysis for Nucleus/Nucleus Collisions

Correlations are sought in support of the theory of the quark/gluon plasma.

A report describes the use of several statistical techniques to characterize the angular distributions of secondary particles emitted in collisions of atomic nuclei in the energy range of 24 to 61 GeV per nucleon. The purpose of this statistical analysis is to determine whether there are correlations between the intensities of emitted particles and angles that confirm the existence of the quark/gluon plasma.

Each technique is presented with some practical details regarding its application. The first technique is the method of composite unit vectors, which enables one to test for azimuthal symmetry in the distribution of an entire set of events. The direction of the ith emitted particle is projected onto the desired azimuthal plane and a unit vector $\hat{\mathbf{r}}_i$ constructed from that projection. A measure of the asymmetry in the angular distribution of the n particles in an event is given by the quantity W

$$W = |\sum_{i=1}^{n} \hat{\mathbf{r}}_i|^2/n$$

For a set of data from many events, the relative probabilities of different values of W can be plotted and compared with an exponential distribution. A deviation from the exponential form would indicate anisotropy in the experiment.

Techniques for the analysis of single events include the χ^2 null-hypothesis test, discrete-Fourier-transform analysis of azimuthal distributions, and a test for nonstatistical fluctuations in pseudorapidity distributions. These techniques provide a quantitative basis for a decision as to whether the distribution of particles emitted in a collision is random or nonrandom and enable the characterization of the distribution in terms of its periodicity. The discrete Fourier transform is particularly useful for the latter function.

One of the events analyzed — an iron nucleus incident on an oxygen nucleus at 55 GeV per nucleon — shows a nonrandom azimuthal distribution with a bimodal character describable by a two-component Fourier representation. The results

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of computer simulations based on the "wounded-nucleon" model of the collision are consistent with the large observed deviation from uniformity. However, there is no evidence of nonstatistical fluctuations in the pseudorapidity function for this or for the other events studied.

This work was done by Stephen C. McGuire of Alabama A. & M. University for **Marshall Space Flight Center**. *Further information may be found in NASA CR-4054 [N87-20813/NSP], "Statistical Analysis of Secondary Particle Distributions in Relativistic Nucleus-Nucleus Collisions."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
MFS-27183

Modeling Plants With Moving-Average Outputs

Three discrete-state-variable representations are derived.

A paper discusses the mathematical modeling of digital control systems for plants in which the outputs include combinations of instantaneous and moving-average-prefiltered measurements. The author derives three discrete-state-variable representations of the behavior of a plant. An example illustrates how to obtain the coefficient matrices in each representation. Guidelines for the choice of the best representation for a plant are given.

The problem is to represent a plant operating in continuous time but driven by r control inputs **u** fed through a zero-order hold of sampling period T. The plant has m instantaneous outputs $\mathbf{y}_I$ and q moving-average-prefiltered outputs $\mathbf{y}_F$, of sampling period T. The instantaneous state of the plant is represented by an n-dimensional vector $\mathbf{x}(t)$, where t = time.

The derivation begins with the basic equations of state at the sampling instants. First, the analysis is applied to a simplified version of the plant with instantaneous output measurements only. Next, the analysis is extended to the fully complex version, in which an instantaneous p-dimensional output vector $\mathbf{z}(t)$ is moving-average sampled at a period of T/N, with sampling weights specified by coefficient matrices H_j to produce the q-dimensional prefiltered output:

$$\mathbf{y}_F(kT) = \sum_{j=0}^{N-1} H_j \, \mathbf{z}[(k-j)(T/N)]$$

where j, k, and N are integers.

The products of the analysis are three alternative sets of discrete-state-variable equations in matrix•vector form. The components of the vectors and matrices can be evaluated exactly by analytical or numerical means. These two representations enable the application of standard techniques to design a feedback controller for the plant. Without these representations, one would have to resort to approximate methods that would be less accurate or would consume much time if iterative.

In the first representation, the state vector of the overall system has $n+q$ dimensions; in the second representation, it has $n+r$ dimensions. If the moving-average-prefiltered output-measurement vector is modified by subtraction of a delayed and otherwise-prefiltered version of the input control vector, one obtains a third representation in which the state vector has n dimensions and the equations of state are those of the simplified version of the plant. The author advises that, where possible, one should choose the representation with the smallest number of dimensions.

This work was done by Michael E. Polites of **Marshall Space Flight Center**. *Further information may be found in NASA TP-2732 [N87-22870], "Modeling Digital Control Systems With MA-Prefiltered Measurements."*

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New Literature



Equipto Electronics Corp., Aurora, IL, is offering a **free modular cabinet catalog** featuring technical data, dimensions, and schematic drawings for an array of modular racks, sloped front consoles, electronic desks, computer furniture, and instrument cabinets. Included are EMI/RFI shielded cabinets for both FCC and TEMPEST requirements.
Circle Reader Action Number 708.

Scientific, medical, and industrial applications of the new **LPX excimer laser** are highlighted in a four-color brochure from Lambda Physik, Acton, MA. The 22-page brochure describes the laser's design innovations, including a new fiber optic local area network that connects distributed intelligent control modules and provides a noise-free communications link into and out of the LPX; menu-driven software for programmed solutions to a variety of operating and maintenance procedures; and a modular design that maximizes uptime.
Circle Reader Action Number 722.

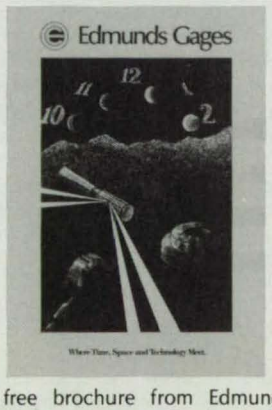


A new brochure describes PTFE- and silicone-coated **fiberglass fabrics, tapes, and belts** manufactured by Taconic Plastics Ltd., Petersburg, NY. Offered free of charge, the brochure includes color photos illustrating typical applications of the fiberglass products in packaging, cooking, printing, and heat-sealing. Special constructions, treatments, and capabilities are also described.
Circle Reader Action Number 718.

Satellite Systems Engineering Inc., Bethesda, MD, has published a new **report on very-small-aperture-terminals (VSATs)** that examines the trend toward consolidation in the space segment market, and the emergence of VSAT network systems as the key product in the ground segment for business communications. The report analyzes data and video applications, discusses system design, and lists VSAT hardware manufacturers and space segment suppliers.
Circle Reader Action Number 702.



Real Time Devices Inc., State College, PA, has released a **product guide describing IBM PC-compatible interfaces**, including four new analog input boards, an analog output board, a digital I/O board, a prototype/development board, and an I/O extender board. The free guide details applications of the interfaces in real-world control and lists hardware specifications. Also described is the Lexicon Series of data acquisition software that comes with each analog input board. Based on Forth-83, the software controls the interface and includes such functions as real-time data collection, plotting, and disk storage of acquired data.
Circle Reader Action Number 716.



A free brochure from Edmunds Gages, Farmington, CT, details the company's line of precision **gaging products** and in-house engineering services. The illustrated brochure highlights gaging applications in the aerospace, appliance, automotive, bearing, machine tool, and munitions industries.
Circle Reader Action Number 714.

The new **Fiber Optic Components Selection Guide** from Honeywell Optoelectronics, Richardson, TX, includes fiber optic modules and modems, connectorized components, LEDs, photo diodes, and integrated transmitters and receivers. The guide contains a variety of conversion tables and charts useful in designing fiber optic systems. The concept of the fiber optic loss budget is also described. This technique allows the designer to verify that the selected components provide the necessary detector sensitivity and optical power input into the fiber to cover the optical losses in the system.
Circle Reader Action Number 710.



Design Components Inc., Franklin, MA, has published a 24-page catalog that describes new **linear motion and positioning products** with SMART SLIDE™, an intelligent component that replaces less flexible pneumatic, hydraulic, cam, or electric limit switch-based linear actuators. This integrated, single-axis system provides programmable travels up to 24 inches at 15 IPS, and is suited for applications requiring repetitive high-speed positioning from two to several thousand stops. Specifications and an application guide are included.
Circle Reader Action Number 720.



"Optics for Industry," a **free catalog** from the Rolyn Optics Co., Covina, CA, highlights a variety of simple and compound lenses, prisms, optical flats/flat glass, flat and concave mirrors, absorption and thin-film filters, beam splitters, reticles, and instruments. The 130-page catalog also includes a guide to the physical properties of common optical materials.
Circle Reader Action Number 706.



The **Pressure, Strain, and Force Measurement Handbook and Encyclopedia**™ from Omega Engineering Inc., Stamford, CT, features selection guides to state-of-the-art products, including transducers that use sputtered semiconductor technology and miniature load cells, smaller than a dime, that measure up to 1,000 pounds. Available free to qualified engineers and scientists, the 368-page publication contains articles on strain gauge applications and on new commercial scale codes.
Circle Reader Action Number 704.

The latest edition of Mutations, a French/English publication describing **space-derived technologies and products available for licensing**, can be obtained free of charge from Novespace of Paris, France. Highlights include a high-performance VLSI symbolic processor, tunable solid lasers, a composites testing machine, ultrastable miniature quartz oscillators, a high-speed optical beam deflector, and a robot designed for precision work on large-scale items. The four-color booklet also features an index of technologies appearing in previous editions, and includes articles on quality management and on insuring high-risk research and development projects.
Circle Reader Action Number 726.



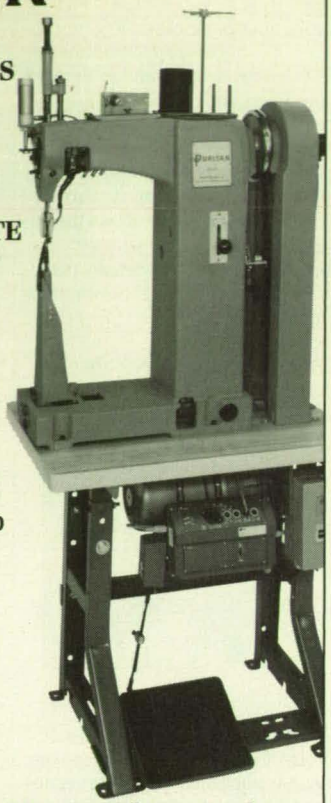
Advanced Purification Systems Inc., Ronkonkoma, NY, is offering a free 80-page **catalog of clean room equipment and supplies**, including laminar flow benches, dessicator cabinets, filters, packaging materials, lab furniture, and accessories.
Circle Reader Action Number 712.

A free brochure spotlights the Introl Corporation's complete line of **cross-development software products**, including Introl-C and Modula-2 cross compiler systems, relocating macro cross-assemblers and support utilities, and IDB source level debuggers. Introl products are available for such development hosts as VAX, Sun, Apollo, Gould, IBM-XT and compatibles, Motorola Delta Series, and various 680XX-based systems running UNIX System V.
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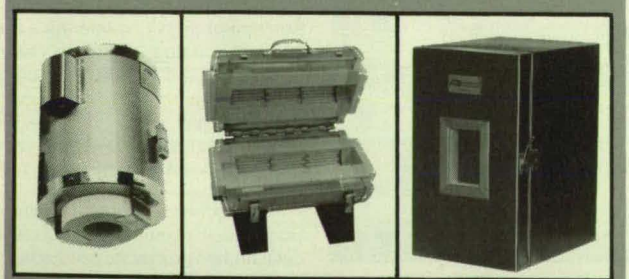
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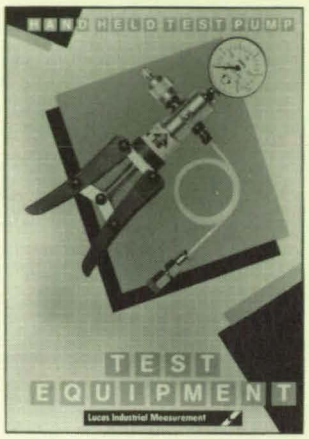
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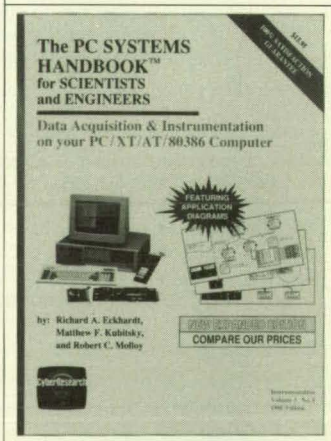
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Circle Reader Action No. 634

New Literature



Lucas Industries' new line of **hand-held analog pumps** for on-site calibration tests is spotlighted in a free four-color brochure. Available in four models, the pneumatically-controlled pumps can measure up to 300 psi of air pressure or 24 inches of mercury vacuum. The brochure also describes pump accessories, including tubing, adapters, washers, seals, gauges, and a lightweight carrying case.
Circle Reader Action Number 734.



CyberResearch Inc., New Haven, CT, is offering an updated edition of the **PC Systems Handbook**™. Available free of charge to qualified engineers and scientists, the 144-page handbook features more than a thousand products for turning 8088-, 80286-, and 80386-based PCs into powerful data acquisition and instrumentation systems. The handbook's many systems designs show users how to configure systems for process control, motion control and robotics, remote data logging, industrial process monitoring, and laboratory automation. The designs contain specifications for each component, wiring diagrams, cables, and software. Also included are charts which evaluate the compatiblity of various combinations of systems and software.
Circle Reader Action Number 740.

A free bulletin from Minco Products Inc., Minneapolis, MN, describes **precision flexible circuitry** for aerospace, military, and medical applications, including single, multilayer, and rigid-flex circuits offering several design choices: stiffeners, pins, connectors, selective bonding, and fine lines down to 0.003 inches. The eight-page bulletin illustrates the benefits of flex-circuits versus conventional wiring, and provides detailed design guidelines.
Circle Reader Action Number 730.



A free 70-page catalog details the complete line of **positioning components and systems** manufactured by New England Affiliated Technologies Inc., Lawrence, MA. Featured are single-axis, X-Y, multi-axis, and rotary positioning stages, as well as stepping and servo motor drives and controls.
Circle Reader Action Number 738.



"Motor Charging Methods," the first in a series of application notes describing **innovations in magnetics**, is now available from Dowty RFL Industries Inc., Boonton, NJ. The publication covers some of the basic methods used to charge barrium-ferrite magnet motors, and discusses typical charging fixtures.
Circle Reader Action Number 736.

A new brochure published by Texcel Inc., Westfield, MA, describes the use of **advanced laser welding methods** for hermetic sealing of products in the aerospace, instruments, controls, and biomedical industries. Applications highlighted include microwave packages, pacemakers, and industrial process controls. New hermetic sealing laser systems and laboratory sealing devices are also discussed.
Circle Reader Action Number 732.

New on the Market



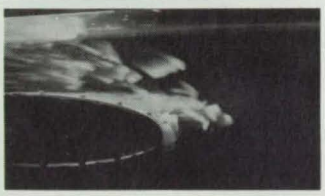
American Graphtec Inc., Irvine, CA, has introduced two new **large format plotters**, both featuring a Motorola 68000 digital servo drive, built-in vector and pen-sorting functions, and an eight-pen turret that accepts a wide range of pen types, widths, and colors. The Model GP1002 has an A to E size plotting area, while the Model GP1102 covers A to D paper sizes. The two pinch roller units offer 31 inches per second plotting speed, 5.6G acceleration, and a 0.0002" mechanical resolution.
Circle Reader Action Number 790.

A new set of **microchips** from Dallas Semiconductor, Dallas, TX, offers proximity data communications—two-way transmission of information through the air. Without connecting wires, products based on the chips can automatically identify and provide data about a tagged object, person, or place, and can link a handheld terminal to a host computer. Comprised of a Micro Power Receiver for listening to low-level signals and a Wire Converter for adding application-specific chips, the chip set is compatible with radio frequency, magnetic, microwave, infrared, or acoustical coupling techniques.
Circle Reader Action Number 778.



BioScan Inc., Edmonds, WA, has introduced the OPTIMAS **measurement and analysis software tool** for scientists, doctors, and other technical professionals who collect, analyze and communicate information from electronic images. Designed for IBM AT or PS/2 computers, OPTIMAS captures images from television cameras, CT scanners, MR imagers, and ultrasound machines. Users can enhance the images with a variety of off-the-shelf image processing hardware and then extract measurements. OPTIMAS data files can be converted to standard ASCII text files which are compatible with statistical analysis packages, spreadsheets, and databases.
Circle Reader Action Number 786.

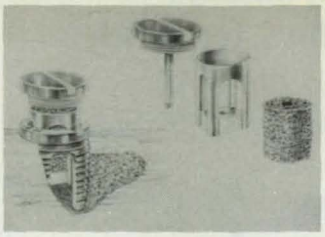
A monolithic 75-MFLOP **floating-point processor** has been developed by United Technologies Microelectronics Center Inc., Colorado Springs, CO. The UT69532 In-phase Quadrature Multiplier Accumulator (IQMAC) vector processor features a pipelined architecture designed to execute a variety of digital signal processing and imaging algorithms, including FFTs, digital filters, matrix operations, and polynomial evaluations. With a 15 MHz clock, the IQMAC performs a 1024-point complex FFT in 683 microseconds. The processor offers six 32-bit data ports, including four bidirectional ports, to reduce or eliminate the I/O bottleneck for complex calculations.
Circle Reader Action Number 784.



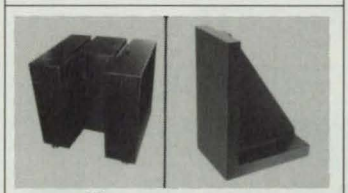
The photo above shows ice being blown from an airfoil's surface by a **powerful new deicer** called the Electro-Expulsive Separation System. This award-winning NASA invention, to be produced commercially by Dataproducts New England Inc., Wallingford, CT, consists of an elastomeric boot embedded with flexible conducting ribbons. Electricity flowing through opposite ends of the conductors forces adjacent conductors violently apart, causing the boot surface to jump and expel the ice. This device uses extremely low power, can remove ice of thicknesses from mere frost to a one inch layer in less than a millisecond, and is easily retrofitted to planes and helicopters.
Circle Reader Action Number 788.



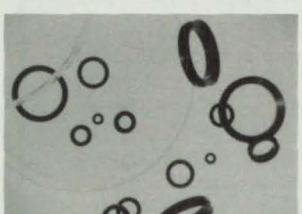
Honeywell Bull Inc., Phoenix, AZ, has unveiled the DPS 9000, a powerful general-purpose **computer system** targeted for high-volume transaction processing, relational database management, and complex networking. The DPS 9000 uses advanced Large Scale Integration technology and a multi-level cache architecture to perform more than 1,000 transactions per second. It also features an integrated vector processor for numerically intensive computing.
Circle Reader Action Number 780.



A tiny device called the **Analytical Bone Implant** (ABI) will provide an important new tool for the study of skeletal diseases such as osteoporosis and problems of bone loss among the elderly and among astronauts confined in the weightlessness of space. It may also help doctors to better understand how a bone fracture heals. Developed jointly by the Southwest Research Institute and the University of Texas Health Science Center in San Antonio, the implant is more reliable and less traumatic to the patient than previous bone research methods, which depended on trephination or drilling samples from the bone. Formed from titanium alloy, the ABI is twelve millimeters long and has three parts: a housing planted deep within the bone; a sample basket into which new bone tissue grows for collection; and a cap for access to tissue samples.
Circle Reader Action Number 782.



Anonite™, a new **polymer composite material** developed by the Anorad Corp., Hauppauge, NY, offers four times the vibration damping of granite, and up to eight times that of cast iron. The material also exhibits a low coefficient of expansion, and can be tailored to meet individual requirements. Anonite can be magnetic, conductive, non-conductive, lightweight or heavy.
Circle Reader Action Number 792.



GBSA Inc., Cleveland, OH, is offering a **V-Seal design kit** to qualified engineers. The V-Seal is a rotary shaft seal that keeps dirt and contaminants out of bearing areas while maintaining lubricants within. Each kit contains nine V-Seals for shaft sizes up to 1-3/8 inches ID. Included is a sample of the new Anti-Friction Treated V-Seal. This treatment reduces friction between the seal and its surface by as much as 75 percent.
Circle Reader Action Number 796.



The **FAX Director** from Data-Doc Electronics Inc., Austin, TX, enables facsimile machines to share existing phone lines automatically, thereby eliminating costly dedicated lines. The FAX Director answers calls on the first ring and initiates a brief greeting or call-forwarding message. All FAX calls are automatically directed to the receiving machine while voice calls are transferred to the telephone system. The FAX Director is compatible with Group II, III, and IV FAX machines, and can be installed on both single- and multi-line (KSU and PBX) telephone systems.
Circle Reader Action Number 794.



The Freestyle™ personal computing system from Wang Laboratories Inc., Lowell, MA, enables IBM-compatible PCs to accept handwritten notes and voice messages, combine them with electronic pages of information displayed on the computer screen, and send the entire packet to similarly equipped systems in a business network. By touching an electronic pencil to a tablet, users can add notes or a signature to a computer document. Spoken words can be placed on the page via a phone-like handset. The data can be organized on-screen using Freestyle's "electronic desktop" function, which allows users to staple, file, move, or mail stamp-size versions of documents.
Circle Reader Action Number 800.



The Model UM-7900 **"smart meter"** from F.W. Bell, Orlando, FL, measures nine parameters: AC current and voltage, DC current, frequency, power factor, phase angle and true, apparent, and reactive power. Designed for use with conductors up to 2-3/8 inches in diameter, the handheld, clamp-on meter is easily interfaced with other instruments via an RS-232 port.
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New on the Market

The DVS-3000 **Image Enhancing Memory System** from Hamamatsu Photonic Systems Corp., Waltham, MA, features 16-bit integration, background subtraction, image zooming, two- and three-dimensional intensity profiling, and distance measurements. The unit is suited for a host of industrial microscopy applications, including semiconductor inspection, and can be used to improve real-time images from x-ray and image-intensified cameras. The DVS-3000 also offers pseudo-color output, gamma correction, recursive filtering, and edge enhancement.
Circle Reader Action Number 774.



The LS010 **Industrial Laser Shutter** from nm Laser Products Inc., Sunnyvale, CA, can handle 10 kilowatts of CO2 laser power continuously, switch beams in 30 milliseconds, and cycle at a 10 hertz repetition rate. A built-in heat exchanger removes the dumped energy. The shutter's unique light trap technology sinks the laser radiation in the device and virtually eliminates backscatter.
Circle Reader Action Number 768.

KEEtutor™, a new **expert systems training kit**, is available from IntelliCorp Inc., Mountain View, CA. The kit contains two videotapes, training software in either tape or floppy format, and five sets of tutorial modules that cover IntelliCorp's KEE® (Knowledge Engineering Environment™) system. One of the videotapes orients new KEE users by illustrating a simple application that models an airport ground traffic controller's assignment of incoming aircraft to gates. The other tape explains how to choose an application and interact with specific task-oriented experts. KEEtutor software is designed for 80386-based PCs, Sun Microsystems, Digital VAXstations, and other popular workstations.
Circle Reader Action Number 772.



The new TouchControl Monitor from MicroTouch Systems Inc., Woburn, MA, offers a low-cost solution for controlling factory floor equipment and other machinery. Available for under $395 in OEM quantities, the **touch monitor** employs a TTL-driven Samsung unit featuring an almost-flat CRT face with an 80-character display capability. Unlike soft plastic touch screens which distort images and are easily scratched in industrial settings, the TouchControl Monitor features a rugged glass sensor with a conductive coating fused to its surface. The high-resolution, scratch-resistant screen comes with a five year manufacturer's guarantee.
Circle Reader Action Number 764.

Schlumberger Technologies Inc., Ann Arbor, MI, has introduced the first two products in its family of MacBRAVO!™ **CAD/CAM software for Macintosh II® computers**. The MacBRAVO! MODELER™ is task-optimized for mechanical design and features "work planes" that simplify 3D modeling by allowing users to define a plane anywhere in space and then design as in 2D. This product also enables modeling of warped, swept, ruled, and offset surfaces, with precision to six digits. The MacBRAVO DETAILER™ operates in conjunction with the MODELER for detailing 3D models, or standalone for 2D design and drafting. The DETAILER uses common mechanical drafting terms and features built-in operations for automatic baseline dimensioning, extensions, fillets, and chamfers.
Circle Reader Action Number 766.



The HUB Material Company, Canton, MA, has introduced a compact 32-piece **electronic tool kit** featuring seven screwdrivers of various sizes, a soldering iron, a burnisher, two pairs of pliers, a wire stripper/cutter, an alignment tool, a flashlight, and many other items. Priced at under $100, the kit comes in a padded zipper case and weighs only 2¾ pounds.
Circle Reader Action Number 770.

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Erratum: In *NASA Tech Briefs* December 1988 issue, page 92, the address given for inquiring into rights for the commercial use of brief MSC-21388 should have read:
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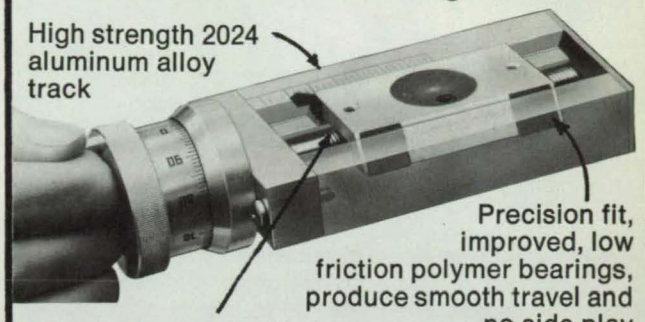
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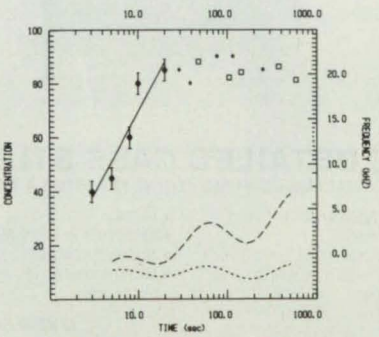
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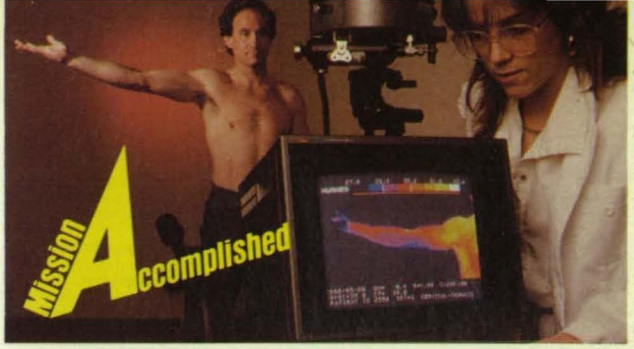


Photo courtesy Hughes Aircraft Co.

Thermography aids in the detection of neuromuscular problems.

Since the time of Hippocrates, physicians have known that body temperature variations offer important clues for diagnosing disease. A localized hot spot on the skin's surface might indicate unseen inflammation, while a cold spot could be symptomatic of poor blood circulation. In the past, however, there was no way to accurately record and measure fluctuating heat emissions. But now, through the rapidly advancing technology of infrared (IR) thermography, physicians have a tool to detect the slight temperature differences that warn of pathology.

Thermographic devices convert invisible IR radiation to a voltage signal that can be viewed directly or displayed on a monitor. The first IR sensors were developed for military purposes such as missile guidance and night vision lenses. Hughes Aircraft Company pioneered the civil application of heat sensors as part of a NASA-sponsored research project. In 1974 Hughes introduced the Probeye® infrared viewer, a monochromatic, handheld instrument which has been used in fire fighting, process monitoring, failure analysis, and many other industrial applications.

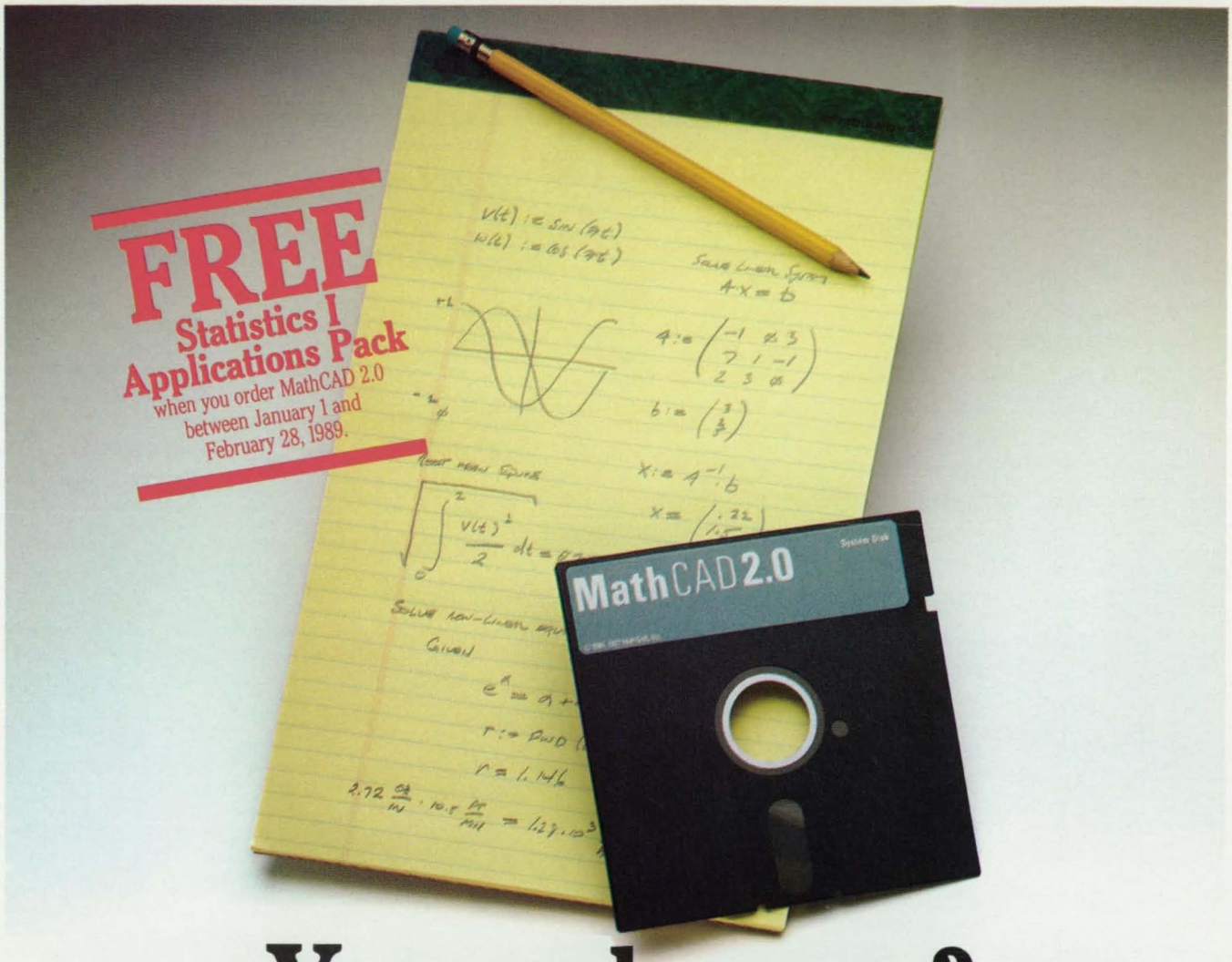
Hughes engineers then took the concept a step further and combined the Probeye with a color television monitor and a high-speed image processor to create the Probeye Thermal Video System. The latest addition to this product line, the Probeye Model 7300, presents real-time infrared "movies" in up to 128 colors, and can sense temperature differences as fine as .01 degrees Celsius.

For medical applications, the thermal video system provides a safe and noninvasive way to observe physiological problems. While other diagnostic tools such as the x-ray show structural anomaly, IR thermography is the only indicator of functional anomaly; it can scientifically verify symptoms. An asymmetrical temperature pattern on the skin, for instance, can indicate the presence of pain. Thermal mapping of dermatones (sections of skin supplied by a specific spinal nerve) enables accurate measurement of nerve dysfunction. A thermograph revealing hot spots on the patient's lower back may indicate nerve irritation, which is difficult to clinically pinpoint.

As a screening tool for diagnosis, thermal imaging can preclude the need to perform more invasive tests that might be dangerous or prolong recovery. It can also be used to monitor a patient's progress during therapy.

Probeye's utility extends to a wide range of industries. Engineers use the video system to detect and locate malfunctions on printed circuit boards (PCBs). "When electricity is applied to a PCB it exhibits a unique thermal signature," explained Dennis Dresser, Senior Applications Engineer for Probeye Infrared Systems. "By comparing the signature of an IR thermographic image of a properly operating PCB with that of a malfunctioning one, the engineer can immediately identify circuitry or components that have failed or most probably will fail."

The imaging technique also helps farmers to spot diseased crops, automobile manufacturers to detect defective parts, and veterinarians to locate injuries in animals. In addition, it may soon be used by museums to study the aging process in artwork. □

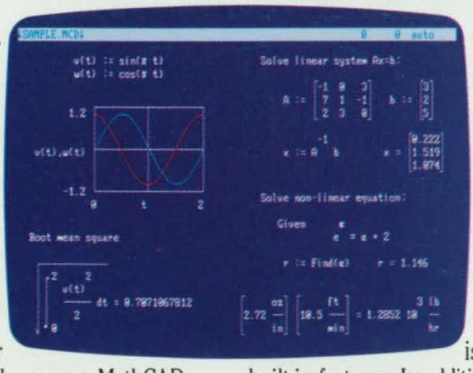


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